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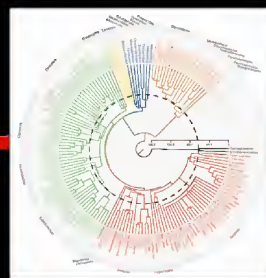
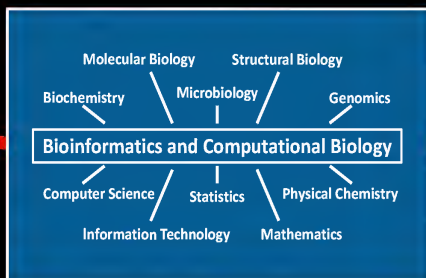
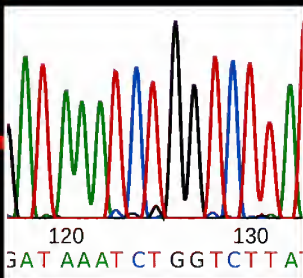
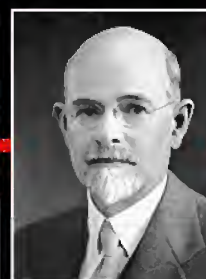
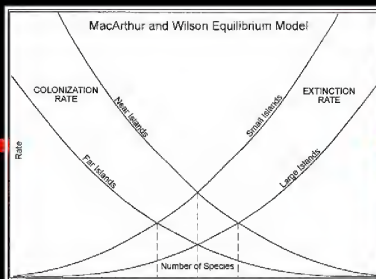
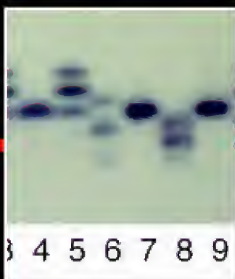
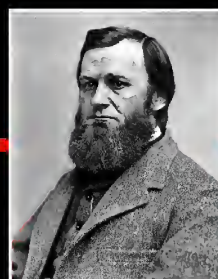
# SPECIAL PUBLICATIONS

Museum of Texas Tech University

Number 66

21 November 2017

## A TIMELINE OF SIGNIFICANT EVENTS IN THE DEVELOPMENT OF NORTH AMERICAN MAMMALOLOGY



DAVID J. SCHMIDLY, ROBERT D. BRADLEY, LISA C. BRADLEY, AND RICHARD D. STEVENS

**Front cover:** This figure depicts a chronological presentation of some of the significant events, technological breakthroughs, and iconic personalities in the history of North American mammalogy. Red lines and arrows depict the chronological flow (i.e., top row – read left to right, middle row – read right to left, and third row – read left to right). See text and tables for expanded interpretation of the importance of each person or event. Top row: The first three panels (from left) are associated with the time period entitled “The Emergence Phase (16<sup>th</sup>–18<sup>th</sup> Centuries)” – Mark Catesby’s 1748 map of Carolina, Florida, and the Bahama Islands, Thomas Jefferson, and Charles Willson Peale; the next two panels represent “The Discovery Phase (19<sup>th</sup> Century)” – Spencer Fullerton Baird and C. Hart Merriam. Middle row: The first two panels (from right) represent “The Natural History Phase (1901–1960)” – Joseph Grinnell and E. Raymond Hall; the next three panels (from right) depict “The Theoretical and Technological Phase (1961–2000)” – illustration of Robert H. MacArthur and Edward O. Wilson’s theory of island biogeography, karyogram depicting g-banded chromosomes, and photograph of electrophoretic mobility of proteins from an allozyme analysis. Bottom row: These four panels (from left) represent the “Big Data Phase (2001–present)” – chromatogram illustrating a DNA sequence, bioinformatics and computational biology, phylogenetic tree of mammals, and storage banks for a supercomputer.

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Layout and Design: Lisa Bradley  
Cover Design: Lisa Bradley  
Production Editor: Lisa Bradley

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This book was set in Times New Roman and printed on acid-free paper that meets the guidelines for permanence and durability of the Committee on Production Guidelines for Book Longevity of the Council on Library Resources.

Printed: 21 November 2017

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Library of Congress Cataloging-in-Publication Data

Special Publications of the Museum of Texas Tech University, Number 66  
Series Editor: Robert D. Bradley

A Timeline of Significant Events in the Development of North American Mammalogy

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ISSN 0149-1768  
ISBN 1-929330-33-2  
ISBN13 978-1-929330-33-1

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# A TIMELINE OF SIGNIFICANT EVENTS IN THE DEVELOPMENT OF NORTH AMERICAN MAMMALOLOGY

DAVID J. SCHMIDLY, ROBERT D. BRADLEY, LISA C. BRADLEY, AND RICHARD D. STEVENS

## ABSTRACT

There has been a long tradition of exploration, collection, and faunal survey in mammalogy that dates back to its origin in North America. From studies that emphasized descriptive taxonomy, morphology, distribution, paleontology, and natural history, mammalogy has transitioned to investigations motivated by the theoretical questions of modern disciplines such as biomechanics, physiology, behavior, genetics, evolution, systematics, ecology, and biogeography. The importance of mammalogy has grown throughout the 20<sup>th</sup> and 21<sup>st</sup> centuries as scientists have found new areas and avenues to apply their knowledge about mammals. Mammalogy today involves a broad range of scientists who study systematics, paleontology, behavior, physiology, ecology, anatomy, biochemistry, and other biological topics, although the degree of individual specialization varies. Modern mammalogy integrates knowledge across all of these disciplines, with molecular biology acting as a major factor. A timeline for the historical development of mammalogy in North America is presented in five phases, beginning with the 16<sup>th</sup> century and continuing to the present.

Key words: history, mammalogy, timeline

## INTRODUCTION

Timelines are particularly useful for conveying the history of a natural science, as they provide a synopsis of chronological events, eras, and topics across a number of centuries (e.g., timeline of the evolutionary history of life). The genesis for this paper occurred when one of us (DJS) attempted to find a timeline for the history of mammalogy. An exhaustive search revealed a 2009 publication, part of *Webster's Timeline History* series, compiled by Philip M. Parker of the European Institute of Business Administration (INSEAD) in Fontainebleau, France. An internet search on Parker revealed that he holds the INSEAD chaired professorship of management sciences, and that he has patented a method to automatically produce a set of similar books from a template with data from databases and internet searches. Parker publishes the automated books through Icon Group International (San Diego, California), and he asserts that his programs have written over 200,000 books (Wikipedia 2017). The 41-page mammalogy timeline is available for purchase from Amazon (cost = \$28.95). Perusal of the contents, however, reveals woefully incomplete details for important North American events and publications

in the discipline. Further, many of the seminal and discipline-changing works are lacking, presumably because the author is not an active mammalogist, or even a biologist, who would be familiar with the impact of such studies.

Fortunately, two mammalogy textbooks (Gunder-son 1976; Feldhamer et al. 2015) contain chapters on the early history of North American mammalogy, and two other papers (Hamilton 1955; D. E. Wilson and Eisenberg 1990) have discussed some of the significant milestones in the discipline. Also, in honor of the 50<sup>th</sup> anniversary of the American Society of Mammalogists (ASM), the *Journal of Mammalogy* published a series of articles about its early history (see Hoffmeister 1969 and Storer 1969), and an entire volume of significant historical developments for North American mammalogy was published on the occasion of the 75<sup>th</sup> anniversary of the ASM (see Birney and Choate 1994). These papers, chapters, and volumes, together with the authors' collective 100 years of knowledge and experience, are integrated herein to provide a timeline of significant events, people, and publications that



have contributed to the development of mammalogy in North America.

The timeline is divided into five phases that, based upon our opinions, represent the state of the science or discipline of mammalogy over a specified time period. Obviously, the definition of each phase title and the assignment of chronological boundaries around each phase are subjective and we assume would differ among any collection of authors. Consequently, we have attempted to characterize the phases based on the availability of knowledge, ideas, or technology that, in general, produced a common scientific theme over a particular time period. In the Emergence phase (16th–18th centuries), mammals and mammalogical information first begin to appear in the accounts about the exploration of the continent. A Discovery phase (19th century) followed, emphasizing the description of species and, in some cases, entire faunas. The Natural History phase (1900–1960) emphasizes the basic life history, distribution, and ecological studies of mammals along with a continuation of taxonomic revisions. The last four decades of the 20th century (1961–2000) comprise what we term the Theoretical and Technological phase of interpreting information about mammals in light of modern evolutionary ecology and systematics theory. Finally, in the Big Data: Molecular Biology and Quantitative Ecology phase (21st century), almost every aspect of mammalogy is being examined and evaluated in light of data garnered using molecular biology and quantitative ecology methods.

The most challenging part of collecting material for the timeline was in setting criteria for evaluating which events to include or exclude. In making this determination, we followed four basic rules or criteria. First, we agreed to limit our focus to events that impacted mammalogy in North America. Given that mammalogy as a research or academic discipline is relatively new (last 60 years, or so) to Central America or Mesoamerica, we further restricted our timeline to include events impacting only the United States, Canada, and Mexico.

Second, we chose to limit our selections to major publications or journals that: 1) defined the distribution and occurrence of mammals for the first time (e.g., accounts of early North American explorers and traders, Harriot 1588); 2) pertained to unstudied geographic

regions (e.g., mammals of a particular region, Mearns 1907); 3) established standards and benchmarks in the reporting of scientific knowledge (e.g., format and style for publications, Hall 1946); 4) reported the appearance of an idea, technique, analysis, statistical test, or equipment item for the first time (e.g., game management, Leopold 1933; bat echolocation, Pierce and Griffin 1938; island biogeography, MacArthur and E. O. Wilson 1967); 5) served in the development of classroom teaching of mammalogy (e.g., textbooks and laboratory manuals, Cockrum 1962; DeBlase and Martin 1974); or 6) furthered the advancement of the discipline of mammalogy (e.g., *Journal of Mammalogy* in 1919; *Journal of Mammalian Evolution* in 1993).

Third, we tried to include organizational events that involved the: 1) formation of professional societies (e.g., American Society of Mammalogists in 1919); 2) formation of agencies and changes to those agencies (e.g., U.S. Biological Survey); or 3) legislative acts and regulatory decisions that have impacted the conservation and management of mammals (e.g., the Lacey Act in 1900).

Fourth, we attempted to use our collective experience, knowledge, and background to highlight events that we deemed important to the discipline of mammalogy. We realize that our choices are subjective based on our expertise and experience; however, we have tried to be as inclusive as possible. Also we recognize that recent events are not yet “historical,” so it is difficult to evaluate an event, idea, or contribution in light of whether it will stand the test of time. Consequently, something that appears to be important or perhaps represents a seminal event in today’s world may not be recognized as such 25 years from now. For example, probably 65–75% of pre-1950s papers and events we have included would be identified as “seminal” by any four professional mammalogists. These events/papers have been around for an extended period of time, they have been critiqued and evaluated, and they have been challenged with new data and ideas. However, the events assigned to our last two phases (Theoretical and Technological – 1961 to 2000, and Big Data: Molecular Biology and Quantitative Ecology – 2000 to present) have not been around a sufficient time to be fully evaluated; consequently, their relevance and ultimately their inclusion is subject to debate.

Full citations for publications referenced in the descriptive text of this article are provided in the Literature Cited section. Citations for those papers listed only in the timeline tables have not been provided in the Literature Cited. However, with the information provided in the tables, the references are easily retrievable.

Within the descriptive text and tables, titles of books and journals appear in italics, and titles of scientific articles and numbered monographs are bounded by quotation marks; italics and quotation marks are omitted within parenthetical citations and in the Literature Cited.

### 16<sup>TH</sup>–18<sup>TH</sup> CENTURIES: THE EMERGENCE PHASE

As western civilization emerged from the Middle Ages, European naturalists began to describe, classify, and study the presence and habits of their native mammals. These studies received added impetus when the voyages of discovery returned from around the world bearing specimens of amazing new kinds of mammals and other living things.

Interest in North American mammals began in earnest when the newly arrived European explorers and colonists began to assess and document its natural resources. The greatest amount of attention by early workers was given to the New England region, with the animals of the middle and the southern colonies receiving much less attention.

Bits of information about mammals of North America during the two-hundred-year-long colonial period appeared in early travelers' accounts, regional histories, and reports of pioneer scientific exploring expeditions, but the total of reliable material was scant. Most of these early writings were not made by professional naturalists but rather by explorers, adventurers, and citizens generally.

As with so many other human endeavors, the initial impetus for this exploration was economic.

Beaver and other furbearers were among the earliest of North America's vast natural resources to be exploited by Europeans. Demand for beaver pelts drove fur trappers and mountain men into parts of the continent that previously had been accessed only by indigenous tribes. The fur trappers did much to stimulate interest in wildlife and exploration when they returned to the outposts of civilization with tales of a vast continent inhabited by animals unknown to Europeans.

Most notable among the early naturalists to visit North America was Mark Catesby, who made two lengthy trips from England to the colonies, one from 1712 to 1719 and a second from 1722 to 1726. In 1748, Catesby completed a two-volume treatise entitled *The Natural History of Carolina, Florida, and the Bahama Islands* (Catesby 1748), in which he provided original descriptions and illustrations of a number of North American mammals. Another significant development was the founding of Charles Willson Peale's natural history museum at his home in Philadelphia, which was the first of its kind in the new country. Other significant milestones in this early phase of mammalogy are presented in Table 1.

Table 1. Significant events in North American mammalogy during the Emergence Phase, 16<sup>th</sup> through 18<sup>th</sup> centuries.

Year(s)	Event
1588	<i>Brief and True Report of the New Found Land of Virginia</i> , by Thomas Hariot, is published in London. This was the first scientific effort to describe the natural resources for any part of the United States. The 44-page account mentions deer, rabbits, opossum, raccoons, squirrels, bears, "lyon," wolves, and "wolfish dogges." Hariot's book underwent 17 editions before the 1620s.
1634	<i>New England Prospect</i> (printed Boston, New England), by William Wood, includes a listing of New England mammals.

Table 1. (cont.)

Year(s)	Event
1651	Fransisci Hernandez de Toledo publishes <i>Nova Plantarum, Animalium et Mineralium Mexicanorum Historia</i> , a new natural history of the plants, animals, and minerals of Mexico, including mammals, a few of which prove to be “fantasy” animals. The book is published in Rome.
1709	John Lawson, surveyor general of the North Carolina Colony, provides a full and detailed account of the mammals of that region in <i>A New Voyage to Carolina</i> .
1748	Mark Catesby completes a two-volume treatise entitled <i>The Natural History of Carolina, Florida, and the Bahama Islands</i> (B. White, London, 2 vols.), in which he provides original descriptions and illustrations of a number of North American mammals. This was one of the finest natural history works of the 18 <sup>th</sup> century.
1748–1751	Peter Kalm, a protégé of Carl von Linne (Carolus Linnaeus), travels in the American colonies. He was a principal contributor to his mentor’s understanding of North American species for successive editions of <i>Systema Naturae</i> .
1750–1804	Georges L. L. Buffon publishes <i>Histoire Naturelle Générale et Particulière, avec la Description du Cabinet du Roi</i> (Imprimerie Royale, Paris, 44 vols.), detailing principally mammals and implying that American species are “shriveled and diminished” both in size and variety because of excessive moisture and less heat than was to be found in Europe.
1758–1759	Carolus Linnaeus publishes <i>Systema Naturae per Regna Tria Naturae</i> , 10th ed. (Laurentii Salvii, Holmiae). This two-volume work is generally cited as the basis for modern taxonomy of living animals. The synonymy of scientific names goes no further back in history, and the binomial system of nomenclature was consistently used for the first time. Linnaeus was best known as a botanist, but he did describe 86 species of mammals in this work.
1784	Charles Willson Peale founds a natural history museum in his home in Philadelphia. Peale’s Museum, a unique institution in its day, became intimately associated with the American Philosophical Society. The specimens housed there became the basis for much of the work on mammals during the early part of the 19th century. In 1814, the Peale Museum was moved to Baltimore and eventually was known as the Municipal Museum of the city of Baltimore.
1785	Thomas Jefferson’s <i>Notes on the State of Virginia</i> (Prichard and Hall, Philadelphia) is published. Jefferson went to considerable pains to amass statistical data that demolished G. L. L. Buffon’s views of American mammals (see Buffon 1750–1804, above).
1799	Thomas Jefferson, then Vice-President of the United States, publishes a paper entitled “A memoir on the discovery of certain bones of a quadruped of the clawed kind in the western part of Virginia” (Transactions of the American Philosophical Society 4:246–260). The mammal turned out to be a fossil ground sloth.
1799–1800	Charles Willson Peale presents a series of public lectures on what is known concerning the mammals and birds of the world.

### 19<sup>th</sup> CENTURY: THE DISCOVERY PHASE

The 19<sup>th</sup> century was an age of exploration in North America. The century began with the travels of Meriwether Lewis, William Clark, and Zebulon Pike, supported by President Thomas Jefferson. Others who contributed to the progress of natural history during this century included trappers and fur traders, whal-

ers, surveyors for the army, and those who searched for the Northwest Passage in the Arctic. The study of American mammals slowly emerged as a separate and distinct field of inquiry following the American Revolution. From the second decade of the 19<sup>th</sup> century, American naturalists began publishing compilations



and original works of considerable scientific merit. Most students of the subject in this period were trained as physicians, men like Richard Harlan, John Godman, James De Kay, and Harrison Allen; but artists, such as John James Audubon, and clergymen, notably John Bachman, made their mark as well. Others with varied backgrounds, including George Ord, Robert Kennicott, Samuel Woodhouse, John LeConte, and Constantine Samuel Rafinesque-Schmaltz, also made important contributions.

It was during this period that the first written works devoted solely to mammals were published; some of these were summary volumes, covering all known mammals from North America or the world, whereas others dealt with specific groups of mammals or even individual species. John James Audubon and his clergyman coauthor, John Bachman, prepared the first major work solely on mammals, with hand-colored illustrations, in the three-volume folio *The Viviparous Quadrupeds of North America* (1845–1848) and the ensuing quarto *Quadrupeds* of 1851 that was variously reprinted.

Another set of explorations, begun in the 1850s to determine routes for a transcontinental railroad, resulted in significant advances in North American mammalogy. After passage of the Pacific Railroad Surveys bill in 1853, the Federal Government sent out surveying parties that were accompanied by physician-naturalists from the U.S. Army Medical Corps. They made mammal collections of enormous breadth and value that were deposited in the newly founded (1846) Smithsonian Institution. These specimens were first studied and described by Professor Spencer Fullerton Baird, whose “General report upon the zoology of the several Pacific railroad routes. Part I. Mammals” (1857; republished as *Mammals of North America* in 1859) provided a state-of-the-art synopsis of the then 758 known species of North American mammals. It was the first full-scale research report on all known mammals (excluding bats and marine mammals) of this continent.

Two individuals in the latter part of the 19<sup>th</sup> century and the early 20<sup>th</sup> century made important contributions. Joel Asaph Allen, first at the Museum of Comparative Zoology at Harvard and from 1895 onward at the American Museum of Natural History, wrote more than 400 papers and reviews in ornithology and mammalogy. His classic contributions include his scholarly monographs on the American bison and North American pinnipeds, as well as many lesser contributions.

The second influential person was C. Hart Merriam, who established the role of the government in mammalian research and in the process gave the discipline the solid underpinning that it had previously lacked (see Schmidly et al. 2016). In 1885, he became Chief of a unit in the Department of Agriculture that within 20 years would become a separate Bureau—the Bureau of Biological Survey. The revolutionary changes brought about by Merriam and his colleagues in the Biological Survey resulted in a critical mass of specimens, records, and other information on mammals. That information, combined with increasing numbers of professional scientists working almost exclusively on mammals, led to the emergence of mammalogy as a separate discipline. Mammalogists were aided greatly by improvements in the development of snap-traps, such as the Cyclone trap and Museum Special.

Finally, during the Discovery phase the cornerstone for all of modern biology, the theory of evolution by natural selection, was first presented to the Linnean Society in 1858 during a joint reading of selected extracts from papers by Charles Darwin and Alfred Russel Wallace. Other scientific developments, including the beginning of modern genetics and the use of experimental manipulations in the course of conducting research, also characterized natural science during this century. These theoretical discoveries of the 19<sup>th</sup> century would eventually set the stage for a more comprehensive understanding of North American mammals. The timeline for this phase (Table 2) summarizes the most important of those events.

Table 2. Significant events in North American mammalogy during the Discovery Phase, 19<sup>th</sup> century.

Year(s)	Event
1804	Meriweather Lewis and William Clark are dispatched by President Thomas Jefferson to explore the new Louisiana Purchase by traveling from St. Louis to the Pacific Ocean and back between May 1804 and September 1806. Lewis, Clark, and the members of their party were the first to report on a number of new small and large mammals, including the pronghorn, grizzly bear, kit fox, mule deer, mountain goat, eastern woodrat, bushy-tailed woodrat, white-tailed jackrabbit, and black-tailed prairie dog. Specimens from the expedition were deposited in Peale's Museum in Philadelphia. Captain Clark's field notes, which contain many of the descriptions, have been published (E. S. Osgood, 1964. The field notes of Captain William Clark, 1803–1805. Yale University Press, New Haven, Connecticut.). Thomas Bewick's <i>General History of Quadrupeds</i> (G. & R. Waite, New York) is published and represents the first American work on mammalogy. It is generally thought that George Ord (whose name does not appear in the volume) contributed the information on mammals.
1805	President Thomas Jefferson sends Lieutenant Zebulon Pike to explore the headwaters of the Mississippi River and, later, the territory between the Arkansas River and Red River. In 1810, Pike publishes <i>An Account of Expeditions to the Sources of the Mississippi, and Through the Western Parts of Louisiana, to the Sources of the Arkansas, Kans, La Platte, and Pierre Juan Rivers; Performed by Order of the Government of the United States During the Years 1805, 1806, and 1807</i> (C. & A. Conrad, Philadelphia). The expedition added to the growing body of knowledge on mammals and other natural history of the western and southwestern United States.
1815	George Ord's "North American Zoology" is the first attempt at a comprehensive compilation of mammals by an American naturalist. It appears anonymously in the third edition of William Guthrie's <i>A New Geographical, Historical, and Commercial Grammar, and Present State of the Several Kingdoms of the World</i> (Johnson and Warner, Philadelphia). Ord's 24-page contribution is the first effort by an American to place American species in some scientific arrangement.
1820	Major Stephen Long leads the expeditions to the Rocky Mountains and up the Mississippi River to survey the Canadian border. Thomas Say was the zoologist on both expeditions, and he collected and described a wealth of natural history material, including mammals, birds, and insects. The Mississippi expedition was recorded by an accompanying geologist, William Keating, whose 1824 report of disappearing wildlife may have been the first expression of our current concerns with endangered species when he clearly linked the disappearance of bison herds to the encroachment of military camps and human settlement. His two-volume record, known as <i>Keating's Narrative</i> (1825), provided an account of the wildlife seen on this journey (an excellent reproduction of the original was published by Ross & Haines Inc., Minneapolis, in 1959).
1821	Anselm G. Desmarest publishes <i>Mammalogie, ou Description des Espèces des Mammifères</i> in Paris. It included a number of North American species.
1825	Richard Harlan, a close friend and supporter of John James Audubon, publishes the first installment of his <i>Fauna Americana</i> (A. Finley, Philadelphia), which treats mammals exclusively. Although it is principally a compilation, based in large measure on Desmarest's <i>Mammalogie</i> , it serves a useful purpose by adding 10 new American species and discussing the role of tooth structure in speciation.
1826–1828	John Godman's <i>American Natural History: Part I: Mastology</i> (H. C. Carey, Philadelphia) appears in three volumes and is the first essential original work on mammals completed by an American. There is much on the habits of the more common species in this report. The illustrations are based on mounted specimens in Peale's Museum.
1829	Sir John Richardson's <i>Fauna Boreali-Americana, or the Zoology of the Northern Parts of British America</i> , which contains a volume on mammals, is published in England (J. Murray, London, 4 vols.).

Table 2. (cont.)

Year(s)	Event
1833	Gloger's Rule, that more heavily pigmented forms of endotherms are found in more humid environments, is established ( <i>Das Abändern der Vögel durch Einfluss des Klima's</i> , August Schulz & Co., Breslau).
1839	Maximilian, Prince of Wied, publishes the two-volume <i>Travels in the Interior of North America</i> (A. Bertrand, Paris), which is accompanied by an atlas of paintings by young Swiss artist Carl Bodmer, including the bison, pronghorn, white-tailed deer, and many more species.
1840	Ebenezer Emmons' <i>Report on the Quadrupeds of Massachusetts</i> (Folsom, Wells, and Thurston Printers, Cambridge) is one of the first reports of mammals in a particular state.
1841–1845	John C. Fremont leads four expeditions into the southwestern United States. These explorations produce many natural history specimens, including mammals, and contribute to our knowledge of the southwestern United States.
1842–1844	James De Kay's five-volume <i>Zoology of New York</i> (W. & A. White & J. Visscher, Albany, New York) is published and includes a volume on mammals. This work includes considerable discussion of extra-limital species and is a useful historical account.
1845–1853	John James Audubon and John Bachman publish the brilliant three-volume <i>Quadrupeds of North America</i> (V. G. Audubon, New York), which is the first substantial report on the mammals of North America. The three volumes encompass 1,071 pages and include 197 species, exclusive of varieties, of which about 160 are figured.
1846	The U.S. Senate passes the act organizing the Smithsonian Institution, which is signed into law by President James K. Polk. At its inception, the Smithsonian was charged with the responsibility for maintaining a museum. Spencer Fullerton Baird was placed in charge of the program in vertebrate zoology and was named first curator in 1850.
1847	Bergman's Rule, that larger bodied endotherms are found in colder climates, is established with the publication of "Über die verhältnisse der wärmeökonomie der thiere zu ihrer grösse" (Göttinger Studien 3:595–708).
1853	The Pacific Railroad Surveys bill is passed in March. It orders the Secretary of War to submit a report to Congress on all practicable railroad routes from the Mississippi to the Pacific. A total of \$150,000 was appropriated to defray the expenses of the surveys of the various routes. Through the efforts of Spencer Fullerton Baird, persons capable of making collections and observations in natural history were assigned to these parties. These expeditions resulted in the most voluminous collections of the time. Baird's study of these collections, particularly the mammals, was precise and stands as a monument in the development of mammalogy in North America.
1854	Mammalian paleontology advances with the publication of "Ancient fauna of Nebraska: A description of remains of extinct Mammalia and Chelonia, from the Mauvaises Terres of Nebraska" by Joseph Leidy (Smithsonian Contributions to Knowledge 6:1–194) in which he describes the remains of extinct mammals.
1857	Spencer Fullerton Baird publishes "General report upon the zoology of the several Pacific railroad routes. Part 1. Mammals" in Vol. 8 of <i>Reports of explorations and survey to ascertain the most practicable and economical route for a railroad from the Mississippi River to the Pacific Ocean</i> (Government Printing Office, Washington, D.C.). The report lists a total of 738 species of mammals. In 1859, the report is reprinted as Part 1 in <i>Mammals of North America: The Descriptions of Species Based Chiefly on the Collections in the Museum of the Smithsonian Institution</i> (J. B. Lippincott & Co., Philadelphia); Part 2 of the 1859 publication is a reprinting of "Special report on mammals of the Mexican boundary survey, with notes by the naturalists of the survey."



Table 2. (cont.)

Year(s)	Event
1858	Charles Darwin and Alfred Russell Wallace independently arrive at the theory of evolution by natural selection. Their joint paper, presented to the Linnean Society in London, began a process of debate and acceptance concerning the ways in which living organisms adapt to changing conditions and the manner by which new species arise.
1859	Charles Darwin publishes <i>On the Origin of Species by Means of Natural Selection or, The Preservation of Favoured Races in the Struggle for Life</i> (Murray, London), which begins a revolutionary period in biology.
1860	The Museum of Comparative Zoology at Harvard University is opened and begins to grow rapidly under the supervision of zoologist Louis Agassiz. Agassiz would become known for his resolute resistance to Darwin's theory of evolution by natural selection.
1862	The federal Department of Agriculture is established, which begins the governmental management and oversight of agriculture and natural resources in the United States.
1864	Harrison Allen publishes the first monograph dealing with the long overlooked American bats, "Monograph of the bats of North America" (Smithsonian Miscellaneous Collections, No. 165, Part 1 of Vol. 7, Washington, D.C.).
1868	Lewis H. Morgan publishes <i>The American Beaver and His Works</i> (J. B. Lippincott, Philadelphia) summarizing what is known about the beaver.
1869	Joseph Leidy publishes "On the extinct mammalia of Dakota and Nebraska: Including an account of some allied forms from other localities, together with a synopsis of the mammalian remains of North America" (Journal of the Academy of Natural Science Philadelphia 7(2):1–472).  The American Museum of Natural History is established in New York City with the leadership of Albert Bickmore, a student of Louis Agassiz. This institution became a mainstay of the field of mammalogy with curators that included Joel Asaph Allen, Roy Chapman Andrews, Harold E. Anthony, T. Donald Carter, John Eric Hill, and George H. H. Tate. The Museum became renowned for its exhibitions and scientific collections as well as its panoramas of the world's cultures.
1870	The American Museum of Natural History purchases the zoological collections of Maximilian, Prince of Wied, and brings them to New York, where they become a valuable addition to the Museum collections. The specimens consisted of about 4,000 mounted birds, 600 mounted "animals" (presumably mammals), and 2,000 fishes and reptiles.
1876	Joel Asaph Allen of the Museum of Comparative Zoology at Harvard publishes <i>The American Bison, Living and Extinct</i> (Cambridge University Press, Cambridge), raising concern about the plight of this iconic mammal in North America.
1877	Elliott Coues publishes "Fur-bearing animals: A monograph of North American Mustelidae, in which an account of the wolverene, the martens or sables, the ermine, the mink and various other kinds of weasels, several species of skunks, the badger, the land and sea otters, and numerous exotic allies of these animals, is contributed to the history of North American mammals" (United States Geological Survey of the Territories, Miscellaneous Publication 8:1–348), a monograph of the North American Mustelidae that becomes a classic of the time and of lasting value.  Elliott Coues and Joel Asaph Allen publish "Monographs of North American Rodentia" (United States Geological Survey of the Territories, Miscellaneous Publication 11:1–1,091), detailing what is known about the largest order of North American mammals (also included Lagomorpha).  Allen's rule, that appendages of endotherms are smaller in colder climates, is established (Radical Review 1:108–140).



Table 2. (cont.)

Year(s)	Event
1878	Spencer Fullerton Baird succeeds Joseph Henry, after the latter's death, as the second Secretary of the Smithsonian.
1879	The U.S. National Museum (now the National Museum of Natural History) is established, under the guidance of Spencer Fullerton Baird, as an adjunct of the Smithsonian Institution in Washington, D.C. Elliott Coues, distinguished ornithologist and mammalogist, is designated as curator of mammals. Baird seems to have been taking care of the mammal collection unofficially, for Coues was the first curator of mammals to be actually appointed. Coues was one of that group of 19 <sup>th</sup> century naturalists of the Medical Corps of the U.S. Army who did such a spectacular job of gathering both information and specimens from the outposts of the western U.S.
1880	Joel Asaph Allen publishes the "History of North American Pinnipeds: A monograph of the walruses, sea lions, sea-bears, and seals of North America" (U.S. Geological and Geographical Survey of the Territories, Miscellaneous Publication 12:1–785), the first monograph of walruses, sea-lions, sea-bears, and seals of North America.
1883	The Cyclone Mouse Trap, designed by John Morris, is patented. This trap and its various modifications, including the Museum Special, opened up new vistas and greatly enhanced the study of mammals.  The American Ornithologist's Union is established as the first scientific society of vertebrate biologists. Many of its members study and/or have interests in mammals. Joel Asaph Allen, Elliott Coues, and William Brewster are the primary organizers.
1884	Elliott Coues writes to <i>The Auk</i> , beginning a successful campaign to establish trinomial nomenclature—the taxonomic classification of subspecies. The use of the subspecies category would become a dominant aspect of mammalogy for the next 75 years.  C. Hart Merriam publishes <i>The Mammals of the Adirondacks</i> (New York: Privately published), which sets a new standard, embodying for the first time fine details of life histories that had not previously been presented in a local work. This publication would establish Merriam's leadership in natural history.
1885	Precursor of the Biological Survey (Section of Economic Ornithology, Branch of the Division of Entomology, U.S. Department of Agriculture) is funded by Congress on 3 March. The small 3-person unit is established with a \$5,000 appropriation and C. Hart Merriam is designated as Chief.  Frederick W. True publishes " <i>A provisional list of the mammals of North and Central America and the West Indian Islands</i> " (Proceedings of the U.S. National Museum 7:587–611), which includes 363 species of mammals.
1886	The U.S. government formally recognizes the value of mammalogy when the Division of Economic Ornithology in the Department of Agriculture is expanded and renamed the Division of Economic Ornithology and Mammalogy and its appropriation is doubled to \$10,000. Under the guidance of C. Hart Merriam, this agency, later to be known as the Bureau of Biological Survey, admirably demonstrated the fruitful interaction between basic and applied research on wildlife resources, particularly mammals.
1889	The <i>North American Fauna</i> series is initiated by C. Hart Merriam to cover a wide range of topics related to aspects of systematics, taxonomy, and natural history of North American mammals. The first issue was a revision of the North American pocket mice by Merriam.  Relationship is established between the U.S. Department of Agriculture and the U.S. National Museum concerning the care and management of specimens resulting from biological investigations by the Biological Survey.

Table 2. (cont.)

Year(s)	Event
1890	C. Hart Merriam publishes “Results of a biological survey of the San Francisco Mountain region and desert of the Little Colorado, Arizona” (North American Fauna 3: 1–136), in which he outlines his life zone concept for North America. While the life zone concept provided insights into the environmental determinants of geographic distributions of species, it was later rejected because of its limited ability to generalize beyond birds and mammals in the mountainous regions of the southwestern United States.
1891	William Henry Flower and Richard Lydekker publish <i>An Introduction to the Study of Mammals Living and Extinct</i> (Adam and Black, London). This work provides an introduction to the structure and function of mammals, with an emphasis on skeletal and dental traits.
1893	The Field Museum is founded as the Columbian Museum of Chicago. In 1905, its name is changed to the Field Museum in honor of benefactor Marshall Field. The museum develops and maintains a large collection of mammals from throughout the world. Wilfred Osgood, a legendary early mammalian taxonomist and the 3 <sup>rd</sup> president of the American Society of Mammalogists, joins the museum in 1909 as a curator of mammals. Osgood became Chief Curator of Zoology in 1921 and served in that role for 20 years until his retirement in 1941.
1896	The Economic Ornithology and Mammalogy division becomes a separate division of the Agriculture Department and is renamed the Division of Biological Survey. C. Hart Merriam continues as Chief. Richard Lydekker publishes <i>A Geographical History of Mammals</i> (Cambridge University Press, Cambridge). This publication provides a list of mammals relative to what Lydekker terms geographical realms.
1897	Edouard Louis Trouessart publishes the first of a six-volume series, <i>Catalogus Mammalium Tam Viventium Quam Fossilium</i> (R. Friedlander und Sohn, Berlin), which includes a concise review of the then known mammals of the world.
1899	William T. Hornaday details the life history and near extinction of the North American bison in “The extermination of the American bison with a sketch of its discovery and life history” (Smithsonian Institution Annual Report, 1887, Washington, D.C., pp 367–548).
1900	The Lacey Act becomes the first Federal law protecting game, controlling the importation of species and prohibiting the interstate shipment of illegally taken wildlife. Enforcement of the Act becomes the responsibility of the Biological Survey.

### 1901–1960: THE NATURAL HISTORY PHASE

During the 20<sup>th</sup> century, mammalogy came into its own as a distinct discipline within the life sciences. Specialization within the discipline increased steadily over the first half of the century as knowledge of mammals increased. This century also saw the beginnings of the conservation movement that would impact mammalogy. In 1900, Congress passed the Lacey Act, the first major piece of federal legislation to protect wildlife, and assigned primary regulatory authority to the Biological Survey. Prior to this, the Survey’s primary role was scientific—in taxonomy, biogeography, and food habits—but with this action the focus slowly gravitated toward more of a regulatory and managerial

role. In 1915, the Survey began to receive congressional appropriations for predator control, and in the 1920s and 1930s it would come into major conflict with the American Society of Mammalogists over its predator control practices.

In the early part of the century, mammalogists were still preoccupied with faunal surveys and documenting the occurrences and distribution of species and subspecies of mammals. Population-level thinking was on the horizon, but most systematists still harbored a typological philosophy. However, as the century moved forward, naturalists increasingly became concerned not

with describing new species, but with understanding what determined the distribution and abundance of the species that they now knew about. Mammalogists also gradually became more interested in ecological questions, especially as information on life histories was acquired. They began to study the lives of wild mammals directly by observation and indirectly by trapping and tracking. The study of North American mammals was passing from a discovery phase to a natural history phase.

Early in the century, the founding of a major academic center for the study of mammalogy and training of mammalogists at the University of California at Berkeley (UC-Berkeley) was due, in large measure, to the efforts of Annie M. Alexander. After traveling on expeditions to Alaska in 1906–1908, she befriended C. Hart Merriam and discussed with him her idea of a museum for the study and preservation of the rapidly disappearing wildlife of the western states. Her proposal to UC-Berkeley was accepted, and in 1908, the museum was established with Joseph Grinnell as its first director. With the continuing support of Alexander, Grinnell developed the Museum of Vertebrate Zoology at UC-Berkeley into a leading center of research and graduate training (see Stein 2001 for a complete discussion of Alexander's numerous accomplishments). The academic side of field mammalogy and its scientific paradigm in North America can be traced directly to Grinnell's work at the UC-Berkeley. Grinnell literally was the first Professor of Mammalogy at an American university.

Harvard, Cornell, and UC-Berkeley were among the only academic institutions to offer course work in mammalogy during the early 1900s. The first doctorate in mammalogy is believed to have been awarded by UC-Berkeley to Walter P. Taylor in 1914 (Sterling 1973). Other academic centers to offer advanced degrees developed in the 1920s at Michigan (led by Lee R. Dice), Cornell in the 1930s (led by William J. Hamilton), and at the University of Kansas in the 1940s (led by E. Raymond Hall). The University of Kansas program became a dynasty, producing publications and scholars that populated and started mammalogy programs at other universities.

The most significant development for mammalogy in this time-frame was the establishment of the

American Society of Mammalogists as the primary scholarly organization for North American mammalogists. When the ASM was founded in 1919, its charter members included some of the most prominent North American biologists. The majority of these were primarily taxonomists, still actively engaged in classifying species and documenting their distributions over the continent. Even though their systematic work represented the culmination of the discovery phase, their studies were becoming increasingly synthetic, analytical, and conceptual. It is no accident that these taxonomists also made some of the most important contributions to natural history.

Another landmark involved the development of community ecology. The first book on the subject was by Victor Shelford (1913), who was the first president of the Ecological Society of America (1915) and a member of the ASM. Shelford's other landmark work was the development of the biome concept, in conjunction with the plant ecologist Frederic Clements (Clements and Shelford 1939).

Many of the taxonomic publications of the 1920s were produced by employees of the Bureau of Biological Survey, although the most important taxonomic catalogue of the period was published by Gerrit S. Miller (1924), Curator of Mammals at the U.S. National Museum, who updated his earlier (Miller 1912) list of North American mammals.

Natural history studies gathered momentum in the 1920s and 1930s, and they continued to dominate ecological mammalogy until the 1950s. Early research (1930s and 1940s) on mammalian population ecology emerged from research on life histories and on wildlife and forest management. The commercial availability of the Sherman Live Trap in 1955, invented by H.B. Sherman in the 1920s, was instrumental in facilitating small mammal research and encouraging life history studies.

The field of wildlife management became prominent with the publication of Aldo Leopold's book *Game Management* in 1933. Four years later, the Wildlife Society was formed and many mammalogists interested in game management became affiliated with this new scientific society.



With the “modern synthesis” in the 1940s (see Huxley 1940), evolution and genetics (especially population genetics) were brought together and provided a more appropriate framework for synthesis with ecology. Mathematical models were developed to characterize the genetic mechanisms of evolutionary change. George Gaylord Simpson, Theodosius Dobzhansky, and Ernst Mayr developed a broad view of evolution that incorporated not only genetic mechanisms, but also systematics, biogeography, paleontology, and ecology. In North American mammalogy, the influence of the new synthesis was seen most clearly in two research programs. One is the work on the genetics of *Peromyscus* by Frances B. Sumner and Lee R. Dice. The other major contribution to the new synthesis was George Gaylord Simpson’s interpretation of the historical record of evolution, based on his studies of fossil and Recent mammals. Simpson also produced the taxonomic highlight of the 1940s with his 1945 publication “The principles of classification and a classification of mammals.”

The 1950s also produced a watershed decade of mammalian taxonomy in North America. An important taxonomic catalogue (“List of North American Recent Mammals,” by Gerrit Miller and Remington Kellogg, 1955) was published that became the standard for modern checklists, only to be over-shadowed five years later by the classic volume, *The Mammals of North America*, published in 1959 by E. Raymond Hall and Keith R. Kelson.

The invention of adding machines, calculators, and computers from the 1950s into the 1970s revolutionized mammalian research and transformed the fields of ecology, population biology, and other disciplines involving hypothesis-based research. Many conceptual and theoretical ideas were advanced as a result of the integration of mathematic and biological principles (e.g., see the works of William Bateson, Sir Ronald A. Fisher, John Maynard Smith, William D. Hamilton, Sewall Wright, and others). Additionally, these new technologies, together with the use of statistical analyses and the emergence of the modern synthesis, allowed ecological mammalogists to begin to explore popula-

tion cycles, niche concepts, and community ecology, as well as biogeography and distributional attributes (see contributions by Charles Elton, G. Evelyn Hutchinson, Robert H. MacArthur, and Edward O. Wilson).

A seminal event in the biological sciences, in general, was the Cold Spring Harbor Symposium in Quantitative Biology held in 1957 (Brown and Wilson 1994). Based on a series of papers in genetics, ecology, and evolution, the “new synthesis” was expanded to include ecology, and the foundations of evolutionary ecology were laid. In the concluding remarks that capped the symposium, George Evelyn Hutchinson presented the theory of the multidimensional niche.

During the 1950s, intraspecific taxonomy of vertebrates came under heavy criticism during a debate on the utility of subspecies that raged largely in the pages of *Systematic Zoology* for 10 years, sparked by Edward O. Wilson and William L. Brown’s epic 1953 paper, which advocated abandoning the subspecies category. North American mammalogists played a critical role in this debate, both criticizing (Burt 1954) and defending the subspecies concept (Durrant 1955) as well as proposing useful solutions to the dilemma (Lidicker 1960, 1962).

Finally, data from mammals began to figure prominently in studies in community ecology. In 1955, Sherman Live Traps became commercially available, which facilitated the capture and study of small mammals and eventually allowed mammalogists to make contributions refining the niche concept with research measuring niche parameters, population dynamics, community organization, foraging, habitat selection, life history traits, and coevolution. Hutchinson and MacArthur (1959) used weasels as examples of the regular ratios in the body sizes of trophic assemblages of coexisting species to illustrate the influence of interspecific competition on community structure. In another article published in the same year, these authors used the frequency distribution of body sizes among all species of North American mammals to develop models of niche relationships and coexistence.



Table 3. Significant events in North American mammalogy during the Natural History Phase, 1901–1960.

Year(s)	Event
1901	Gerrit S. Miller, Jr. and James A. G. Rehn publish “Systematic results of the study of North American land mammals to the close of the year 1900” (Proceedings of the Boston Society of Natural History 30:1–352), which includes 1,450 species of mammals.
1902	<p>C. Hart Merriam, who would later become the first president of the American Society of Mammalogists, is elected to the National Academy of Sciences, one of the most prestigious recognitions in American science.</p> <p>Frank Evers Beddard’s volume “Mammalia,” Volume 10 in the <i>Cambridge Natural History</i> series, is published (Macmillan and Co., London). This publication (similar to Gerrit Miller and James Rehn’s 1901 work) provides a list and discussion of Recent mammals.</p> <p>The American Society of Zoologists is established when members of the Central Naturalists and American Morphological Societies merged. In 1996, the society changed its name to the Society for Integrative and Comparative Biology. This provides early mammalogists with a professional society and access to a journal.</p>
1903	<p>The short-lived Pacific Coast Mammalogical Club, with Joseph Grinnell as one of the founders, is apparently the first attempt to form a professional mammalogy society in North America.</p> <p>The first Federal Bird Reservation is established by President Theodore Roosevelt on Pelican Island, Florida, and placed under the jurisdiction of the Biological Survey. Pelican Island and other early Federal wildlife reservations are re-designated as “national wildlife refuges” in 1942.</p>
1904	<p>“Index generum mammalium: A list of the genera and families of mammals” by Theodore S. Palmer is published (North American Fauna 23:1–984).</p> <p><i>Die Säugetiere. Einführung in die Anatomie und Systematik der recenten und fossilen Mammalia</i> by Max Weber is published (Gustav Fischer, Jena). It includes up-to-date accounts of general structure, function, and biology, plus a worldwide systematic review of the class Mammalia.</p>
1905	<p>The Division of Biological Survey is expanded and renamed the Bureau of Biological Survey. This agency remains under the U.S. Department of Agriculture with C. Hart Merriam as its Chief.</p> <p>Daniel G. Elliot publishes “A check list of mammals of the North American continent, the West Indies, and the neighboring seas” (Field Columbian Museum Publication 105, Zoological Series, 6:1-761).</p>
1907	<p>Edgar Alexander Mearns publishes “The mammals of the Mexican boundary of the United States” (Bulletin U.S. National Museum 56:1–530), after having served as naturalist and medical-officer to the Mexico-United States International Boundary Commission. Mearns contributed more than 30,000 plant and animal specimens to the National Museum, including over 7,000 mammals. Mearns’ account covered the border region from El Paso, Texas, to the Pacific Ocean.</p> <p>Glover Morrill Allen, who had received his Ph.D. from Harvard in 1904, joins the faculty of the Museum of Comparative Zoology as Curator of Mammals. He was the first to offer instruction in mammalogy at Harvard.</p> <p>Gerrit S. Miller, Jr. publishes “Families and genera of bats” (Bulletin U.S. National Museum 57:1-282). This is the first comprehensive systematic treatment of bats.</p>
1908	Joseph Grinnell, through a generous donation from Annie M. Alexander, establishes the Museum of Vertebrate Zoology in the University of California at Berkeley. This becomes the first public academic center for mammalogy in the United States.
1909	Marcus Ward Lyon, Jr., and Wilfred H. Osgood publish “Catalogue of the type specimens of mammals in the United States National Museum, including the Biological Survey collection” (U.S. National Museum Bulletin 62:287–292).

Table 3. (cont.)

Year(s)	Event
1910	<p>Wilfred H. Osgood publishes "Revision of the mice of the American genus <i>Peromyscus</i>" (North American Fauna 28:1–285), considered by many to be the classic taxonomic revision of the early 20<sup>th</sup> century. Osgood examined more than 27,000 museum specimens and began to incorporate the concepts of clinal, geographic, age, and sexual variation into systematics.</p> <p>Henry Fairfield Osborn publishes <i>The Age of Mammals in Europe, Asia, and North America</i> (Macmillan Co., New York).</p> <p>William K. Gregory publishes "The orders of mammals" (Bulletin American Museum of Natural History 85:1–350), which gives an account of extant and fossil orders of mammals.</p> <p>The first formal course in mammalogy (listed in the institutional catalog) is offered at the University of California at Berkeley. Graduate seminars in the subject previously had been offered at Harvard.</p> <p>The Biological Survey collections are moved from the U.S. National Museum to the newly constructed National Museum of Natural History, and Biological Survey personnel associated with the collections are provided office space in the Natural History Museum. The Biological Survey collection of birds and mammals would remain separate from those of the Smithsonian Institution until their integration in 1946 (birds) and 1953 (mammals).</p>
1912	<p>Gerrit S. Miller, Jr. publishes "List of North American land mammals in the United States National Museum, 1911" (Bulletin of the U.S. National Museum 79:1–455). This publication serves as the guide for style and format for subsequent checklists. This publication was revised and renamed in 1924 ("List of North American recent mammals, 1923", Bulletin of the U.S. National Museum 128:1–673).</p>
1913	<p>William B. Scott publishes <i>History of Land Mammals in the Western Hemisphere</i> (The Macmillan Co., New York). This publication provides a geologic and geographic perspective, classification, discussion of teeth and other anatomical structures, as well as a treatment of fossil and Recent forms.</p> <p>The mammalian ecologist Victor Shelford publishes the first book on animal and plant communities, <i>Animal Communities in Temperate North America</i> (University of Chicago Press, Chicago).</p> <p>Charles C. Adams, a mammalian ecologist, publishes the first manual on animal ecology, <i>Guide to the Study of Animal Ecology</i> (The Macmillan Co., New York). This publication established a format for life history studies.</p>
1914	<p>The first doctorate in mammalogy is awarded by the University of California at Berkeley to Walter P. Taylor, who spends his career working for the Biological Survey.</p>
1915	<p>Professor Alfred Hazen Wright offers a formal course in mammalogy at Cornell University.</p> <p>Congress appropriates \$125,000 to the Bureau of Biological Survey for predator control.</p> <p>The Ecological Society of America is founded with Victor Shelford elected as its first President. Many mammalogists join this society and participate in its activities, including publishing in the journal <i>Ecology</i>.</p> <p>William Diller Mathews publishes "Climate and evolution" (Annals of the New York Academy of Sciences 24:171–318), which establishes the foundations of modern historical biogeography. A second edition was published in 1939.</p>
1916	<p>Edward W. Nelson, a mammalogist of considerable renown, assumes the role of Chief of the U.S. Biological Survey, a position that he holds until 1927.</p> <p>The National Park Service is officially established to provide oversight and management of the growing number of national parks being designated in the U.S. National parks become major centers for the conservation and viewing of mammals.</p>

Table 3. (cont.)

Year(s)	Event
1916–1918	The National Geographic Society publishes two popular accounts of North American mammals written by Edward W. Nelson of the U.S. Biological Survey (1916, “The larger North American mammals,” National Geographic Magazine 30:385–472; and 1918, “Smaller mammals of North America,” National Geographic Magazine 33:371–493).
1917	Joseph Grinnell publishes a seminal article (Auk 34:427–433) outlining the niche concept (in ornithology). Ahead of its time, Grinnell’s niche concept is later refined and formalized by G. Evelyn Hutchinson (see Table 4, 1957).
1918	The Migratory Bird Treaty Act is passed implementing the convention between the United States and Great Britain (for Canada) for the protection of migratory birds. The Act, a landmark in wildlife conservation legislation, provides for the regulation of migratory bird hunting.
1919	The American Society of Mammalogists is established by an organizational meeting held on 3 and 4 April at the U.S. National Museum, and 252 charter members are designated. C. Hart Merriam is elected President and Joel Asaph Allen as Honorary Member. The first issue of the <i>Journal of Mammalogy</i> is printed. The ASM has since become the largest professional group in the world whose main focus is the biology of mammals.  Lee R. Dice begins guiding graduate students working on programs concerning mammals, his first year at the University of Michigan, with formal course work to follow early in the 1920s. This marks the beginning of the University of Michigan as a major center for academic mammalogy.
1922	Angel Cabrera publishes <i>Manual de Mastozoología</i> (Compania Anonima de Libreria, Madrid and Barcelona). Cabrera’s book provided anatomical and structural descriptions for many mammals.
1924	Increasingly at odds with the Biological Survey over its predator control program, the ASM at its annual meeting at Harvard University votes to direct its President to appoint a committee to report on the Survey’s predator control work. The committee, which included both Survey scientists and academic mammalogists, never reached a consensus and ultimately issued two separate reports in 1928.
1925	The first volume of Ernest Thompson Seton’s <i>Lives of Game Animals</i> (8 volumes) (Doubleday & Co., Inc., Garden City, New York) is published. The volumes (1925–1928) provide summaries of the natural history and biology of the major game species in the United States.
1926–1928	Three <i>Monographs of the American Society of Mammalogists</i> are published, one in each of the three years. These were: number 1 (1926), “Anatomy of the Wood Rat” by A. Brazier Howell; number 2 (1927), “The Beaver” by Edward R. Warren; and number 3 (1928), “Animal Life of the Carlsbad Cavern” by Vernon Bailey.
1928	The Office of Ornithology and Mammalogy within the Bureau of Biological Survey is given “Division” status and renamed Division of Economic Investigations. The next year it would become the Division of Predatory Animal and Rodent Control.  Harold E. Anthony publishes the first popular manual <i>Field Book of North American Mammals</i> (G. P. Putnam Sons, New York) for the amateur naturalist.
1930	The American Society of Mammalogists issues a statement concerning predator control abuses. Congress holds oversight hearings as a result and nearly cancels \$1M in funding to the Biological Survey. The ASM establishes the Membership Committee to encourage persons with an interest in mammals to become members of the society. Membership in ASM breaks the 1,000 mark.
1931	President Herbert Hoover signs the Animal Damage Control Act, which authorizes the Secretary of Agriculture to “promulgate the best methods of eradication suppression or bringing under control” on both public and private lands a whole host of mammalian species, including “mountain lions, wolves, coyotes, bobcats, prairie dogs, and gophers.”



Table 3. (cont.)

Year(s)	Event
1932	Junius Henderson and Elberta Louise Craig publish <i>Economic Mammalogy</i> (Charles C. Thomas, Baltimore), which summarizes much detail on the food habits of North American mammals.
1933	Aldo Leopold publishes <i>Game Management</i> (Charles Scribner's Sons, New York) and accepts a professorship in game management at the University of Wisconsin, the first of its kind in the United States. Leopold and his students provided some of the first ecological studies on wild mammals that could be applied directly to conservation and management.
1934	The Section of Predator and Rodent Control is established as part of the Division of Game Management in the Bureau of Biological Survey. In 1938 it becomes the Division of Predator and Rodent Control (PARC).
1937	<p>The Wildlife Society is founded to reflect the growing interest in the restoration of wildlife populations and the emergence of the new profession of game management. The key founders include Aldo Leopold, Olaus Murie (mammalogist), and ornithologist Waldo McAtee. Volume 1 of <i>The Journal of Wildlife Management</i> is published.</p> <p>Congress passes the Federal Aid to Wildlife Restoration Act. Often called simply the Pittman-Robertson (P-R) Act, it places a federal excise tax on the manufacture of sporting arms and ammunition and makes the revenue available to state wildlife conservation agencies on a matching basis for wildlife restoration projects.</p> <p>Theodosius Dobzhansky publishes <i>Genetics and the Origin of Species</i> (Columbia University Press, New York), a key work of what is to become known as the modern evolutionary synthesis.</p>
1938	G. W. Pierce and Donald Griffin develop the ultrasonic recorder or "bat detector" to detect, display, and record the echolocation calls of bats. Today, these small, hand-held devices are one of the major tools for studying bats.
1939	<p>William J. Hamilton publishes <i>Mammals of Eastern United States</i> (McGraw-Hill, New York), a manual with keys, distribution, and natural history of mammals east of the Mississippi River.</p> <p>The Bureau of Biological Survey is transferred from the U.S. Department of Agriculture to the U.S. Department of the Interior (along with the Bureau of Fisheries from the U.S. Department of Commerce).</p> <p>Frederic E. Clements and Victor E. Shelford publish <i>Bioecology</i> (John Wiley &amp; Sons, New York) describing the biomes of North America, which attains wide use by mammalogists.</p>
1940	<p>George Gaylord Simpson publishes "Mammals and land bridges" (<i>Journal of the Washington Academy of Sciences</i> 30:137–163), which establishes the concept of faunal interchange.</p> <p>John R. Ellerman and his associates issue the first of three volumes on <i>The Families and Genera of Rodents</i> (British Museum of Natural History, London), which includes a large critical review of the most populous order of mammals.</p> <p>Julian S. Huxley publishes <i>The New Systematics</i> (Oxford University Press, Oxford), in which he and 21 other authors of essays outline the theory and philosophy of systematics as understood at that time.</p> <p>The Wildlife Division of the National Park Service is transferred to the Biological Survey.</p>
1941	Bureau of Biological Survey and Bureau of Fisheries are combined to create the Fish and Wildlife Service, U.S. Department of the Interior.
1942	Charles Elton publishes <i>Voles, Mice, and Lemmings</i> (Clarendon Press, Gloucestershire, UK) describing the population cycling of microtine rodents. This was an early classic in population dynamics of small mammals.



Table 3. (cont.)

Year(s)	Event
	Glover M. Allen's volume <i>Extinct and Vanishing Mammals of the Western Hemisphere with the Marine Species of All the Oceans</i> (American Commission for International Wildlife Protection, New York) is published.
	Ernst Mayr publishes <i>Systematics and the Origin of Species</i> (Columbia University Press, New York). This volume establishes the Biological Species Concept, which defines a species as a group of interbreeding natural populations that is reproductively isolated from other such groups. This became one of the most popular species concepts used in mammalogy until the 1990s when it began to be replaced by proponents of the Phylogenetic Species Concept.
	Julian S. Huxley publishes <i>Evolution: The Modern Synthesis</i> (Allen & Unwin, London) that bridges the gap between the work of geneticists, naturalists, and paleontologists to establish the modern view of evolutionary biology for the early 20 <sup>th</sup> century. This work and his 1940 book heavily influence mammalian systematics from World War II up to the 1980s.
	Arthur J. Poole and Viola S. Schantz publish "Catalog of the type specimens of mammals of the United States National Museum, including the Biological Survey collection" (U.S. National Museum Bulletin 178:1–705).
1943	George Gaylord Simpson publishes "Mammals and the nature of continents" (American Journal of Science 241:1–31). He concludes the distribution of mammals in the northern and southern continents is consistent with the theory of stable continents as opposed to continental drift.
	Lee R. Dice publishes <i>The Biotic Provinces of North America</i> (University of Michigan Press, Ann Arbor) in which he proposes a new system and map for the ecological divisions of North America including mammals.
	William H. Burt publishes "Territoriality and home range concepts as applied to mammals" (Journal of Mammalogy 24:346–352), defining two of the most important concepts in mammalian ecology.
1944	George Gaylord Simpson publishes <i>Tempo and Mode in Evolution</i> (Columbia University Press, New York) in which he integrates the facts of paleontology with those of genetics and natural selection. He argues that the processes of the microevolution of population genetics is sufficient to explain the patterns of macroevolution observed by paleontology.
	E. Raymond Hall, formerly Acting Director of the Museum of Vertebrate Zoology at UC-Berkeley, becomes Director of the University of Kansas Museum of Natural History and Chairman of the Zoology Department, thereby establishing a dynasty in research and graduate education focused on mammals. KU becomes a major center for mammalogy research and education in the decades of the 1940s, 50s, and 60s.
1945	George Gaylord Simpson publishes a bibliographic landmark for mammalogy "The principles of classification and a classification of mammals" (Bulletin of the American Museum of Natural History 85:1–350) in which he postulates a higher classification for mammals at the suborder and ordinal levels.
	J. Kenneth Doult, A. Brazier Howell, and William B. Davis publish "The mammal collections of North America" (Journal of Mammalogy 26:231–272), which is the first attempt to put together a comprehensive account of all the known mammal collections.
1946	The International Convention for the Regulation of Whaling meets in Washington, D.C. and establishes the International Whaling Commission (IWC), which is charged with reviewing harvests and establishing quotas for whale stocks.
	Rudolph Martin Anderson publishes "Catalogue of Canadian Recent mammals" (National Museum Canada Bulletin 102:1–238) resulting from his lifetime study of the mammals in the Canadian Provinces.

Table 3. (cont.)

Year(s)	Event
	Sydney A. Asdell's <i>Patterns of Mammalian Reproduction</i> (Comstock Publishing Company, Ithaca, New York) is published in which the author collates most of the data bearing on the reproductive behavior of wild as well as domestic mammals.
	E. Raymond Hall publishes <i>Mammals of Nevada</i> (University of California Press, Berkeley), which sets a new standard for producing state mammal surveys.
1947	Victor H. Cahalane, of the U.S. National Park Service, publishes <i>Mammals of North America</i> (Macmillan Co., New York), an early attempt at a general account about the natural history of mammals, emphasizing mammals that are common in national parks.
	George Gaylord Simpson publishes "Holarctic mammalian faunas and continental relationships during the Cenozoic" (Bulletin of the Geological Society of America 38:361–389), as study of the history of the mammalian faunal interchanges across the Bering Land Bridge.
1948	The International Union for the Conservation of Nature (IUCN) is formed as an independent international organization. The charge of IUCN is to promote wise and sustainable use of the world's natural resources and to document concern for depleted species.
1950	Willi Hennig publishes <i>Grundzüge einer Theorie der Phylogenetischen Systematik</i> (Deutscher Zentralverlag, Berlin). This basic outline of the theory of phylogenetic systematics, at first obscure and controversial, founds cladistics and is mainstream by 1980.
	The Wildlife Society publishes the first <i>Wildlife Monograph</i> , a series that would include many accounts of game mammals.
1951	John R. Ellerman and Terence C. S. Morrison-Scott publish <i>Checklist of Palaearctic and Indian Mammals 1758–1946</i> (British Museum of Natural History, London) which, when used with Miller-Kellogg's North American list (see below), afforded a perspective of the mammalian fauna over most of the Northern Hemisphere.
	Edward A. Goldman publishes "Biological investigations in Mexico" (Smithsonian Miscellaneous Collections 115:1–476) summarizing the life zones and collecting localities for the biological survey of Mexico conducted by Goldman and Edward W. Nelson in the late 19 <sup>th</sup> and early 20 <sup>th</sup> centuries.
	Remington Kellogg, noted mammalogist, Director of the U.S. National Museum, and 16 <sup>th</sup> president of the ASM (1947–1949), is elected to the National Academy of Sciences.
1951	Bryan Glass publishes <i>Key to the Skulls of North American Mammals</i> (self-published, printed at Oklahoma State University, Stillwater). This publication serves as a laboratory manual for many mammalogy courses. Glass published a second edition in 1973, and a third edition, coauthored with Monte L. Thies, was published in 1997. Thies sole-authored a fourth edition in 2015, published by Kendall Hunt Publishing Company, Dubuque, Iowa.
1952	William Henry Burt's and Richard P. Grossenheider's <i>A Field Guide to the Mammals</i> (Houghton Mifflin Co., Boston), the first pocket book on the natural history of North American mammals, is published. This work was reprinted and revised in 1964 and 1972.
1953	James Watson and Francis Crick, with contributions from Rosalind Franklin and Maurice Wilkins, discover the double helix structure of DNA, which would revolutionize all of the biological science disciplines.
	L. R. Conisbee publishes <i>A List of the Names Proposed for Genera and Subgenera of Recent Mammals from the Publication of T. S. Palmer's 'Index Generum Mammalium' 1904 to the end of 1951</i> (British Museum, London) as an addendum to Palmer's original book length publication.
	George Gaylord Simpson publishes <i>Evolution and Geography: An Essay on Historical Biogeography, with Special Reference to Mammals, Condon Lectures</i> (Oregon State System of Higher Education).

Table 3. (cont.)

Year(s)	Event
	Edward O. Wilson and William L. Brown, Jr., publish “The subspecies concept and its taxonomic application” ( <i>Systematic Zoology</i> 2:97–111), in which they criticize the use of the trinomen category in taxonomy. This triggers considerable debate among mammalogists where there has been a long history of its usage (e.g., William H. Burt. 1954. The subspecies category in mammals. <i>Systematic Zoology</i> 3:99–104; Stephen D. Durrant. 1955. In defense of the subspecies. <i>Systematic Zoology</i> 4:186–190; and William Z. Lidicker, Jr. 1962. The nature of subspecies boundaries in a desert rodent and its implications for subspecies taxonomy. <i>Systematic Zoology</i> 11:160–171).
	Ernst Mayr, E. Gorton Linsley, and Robert Usinger publish <i>Methods and Principles of Systematic Zoology</i> (McGraw-Hill, New York). The work was revised by Mayr and retitled <i>Principles of Systematic Zoology</i> (McGraw-Hill, New York) in 1969. A second edition, authored by Mayr and Peter Ashlock, was published in 1991. This book articulated the common principles behind much of the systematic and taxonomic work in mammalogy.
1954	Walter Dalquest applies the use of silk Japanese “mist nets” (used by the Japanese for centuries to capture birds) to capture bats. This revolutionizes the study of bats and remains today the most effective method available for capturing them.
	Francois Bouliere publishes <i>The Natural History of Mammals</i> (Alfred A. Knopf, New York), an excellent synthesis of the life history and habits of the world’s mammals. The book is revised in 1964 and 1970.
1955	Gerrit S. Miller, Jr. and Remington Kellogg publish “List of North American Recent Mammals” (U.S. National Museum Bulletin 205:1–954), which includes 3,622 species and subspecies.
	E. Lendell Cockrum publishes a <i>Laboratory Manual of Mammalogy</i> (Burgess Publishing Company, Minneapolis) as a tool for teaching college courses. The book is revised and reissued by the same author and publisher in 1957 as a <i>Manual of Mammalogy</i> .
	The Sherman Live Trap, which had been invented in the 1920s by H. B. Sherman, becomes commercially available. It becomes used extensively by mammalogists to capture small mammals, such as mice, voles, shrews, and chipmunks, thereby greatly facilitating the study of small mammal populations. Other trap designs (Havahart, National, Tomahawk, etc.) quickly follow suit in producing lightweight folding traps of varying sizes.
	Tao-Chiuh “T. C.” Hsu joins the faculty of University of Texas M.D. Anderson Hospital and Tumor Institute (now known as M.D. Anderson Cancer Center) and begins cytogenetic studies of humans. Hsu later applies these techniques to cytogenetics of numerous mammalian species, paving the way for many mammalogists to use these techniques in systematic and population studies.
1957	G. Evelyn Hutchinson (Concluding Remarks, Cold Harbor Symposium on Quantitative Biology 22:415–427) develops the niche concept. In contrast to Grinnell, who considered a species niche to represent the habitat in which it is found and its accompanying behavioral adaptations, the Hutchinsonian niche was more objective, quantifiable, and comprehensive and is characterized by an n-dimensional hypervolume of conditions and resources that are necessary for the persistence of an organism in its environment.
	The journal <i>Primates: A Journal of Primatology</i> is established to publish original articles concerning various areas of primate research. This is perhaps the first example of dividing mammalogy into specialized journals.
1958	<i>Listening in the Dark</i> (Yale University Press, New Haven, Connecticut) is published by Donald Griffin reporting the author’s varied findings on echolocation and related affairs in the lives of bats.
	Denny Constantine develops the “harp trap” for capturing live bats. The trap is particularly effective around caves with large concentrations of these animals.



Table 3. (cont.)

Year(s)	Event
1959	Bird and Mammal Laboratories, a division of the U.S. Fish and Wildlife Service, are created. These organizations were designed to focus on contemporary research questions.
	E. Raymond Hall and Keith Kelson publish their systematic treatise <i>The Mammals of North America</i> (Ronald Press, New York, 2 vols.) with keys for identification, descriptions, measurements, and 500 distributional maps. This was the landmark publication of its time for North American mammalogy. A second edition, authored solely by Hall, was published in 1981.
	The Craighead brothers, John and Frank, partner with a defense contractor to devise the first large animal radio-tracking collar to study grizzly bears in Yellowstone. Today, radio-telemetry is a major technique for tracking the movements of both small and large mammals.
	G. Evelyn Hutchinson and Robert H. MacArthur, in their famous publication “A theoretical ecological model of size distributions among species of animals” ( <i>The American Naturalist</i> 93:117–129), uses the frequency distribution of body sizes among all species of North American mammals to develop models of niche relationships and coexistence.
1960	G. Evelyn Hutchinson, in “Homage to Santa Rosalia, or why are there so many kinds of animals” ( <i>The American Naturalist</i> 93:145–159), uses weasels as an example of the regular ratios in the body sizes or trophic assemblages observed among coexisting species that reflect the influence of interspecific competition on community structure.
	ASM establishes the International Relations Committee to maintain and enhance communication between ASM and mammalogists outside of North America. This leads to international meetings and the subsequent development of mammalogy throughout Latin America.
	T. C. Hsu develops the <i>Mammalian Chromosomes Newsletter</i> , which is published through 1986 by M.D. Anderson Hospital, for reporting results of chromosome variation in mammals.
	Henry S. Masby edits the <i>Manual of Game Investigational Techniques</i> (The Wildlife Society, Wildlife Techniques Committee, Ann Arbor, Michigan). This textbook (and its subsequent editions) is the primary text for wildlife management techniques courses and outlines many standard techniques commonly used for collecting and studying mammals.

### 1961–2000: THE THEORETICAL AND TECHNOLOGICAL PHASE

In the late 1950s and 1960s, a major emphasis on science in the U.S. and Canada was stimulated by military and scientific competition of the Cold War era with the former U.S.S.R., the need for zoonotic and disease information during the Korean and Vietnam wars, and the overall scientific build up for the Space Program. One of the major technological advancements was in the development of computers and the accompanying improvements in statistical software that increased the ability to more thoroughly analyze data. These events prompted a transition from descriptive, specimen-based research toward a more hypothesis-driven scientific approach, and in some cases a more biomedical slant. This ever-changing state-of-the-science allowed mammalogy to become more sophisticated and focused.

New technologies allowed one to ask more questions and better address old ones. Subsequently, many technological breakthroughs steadily appeared that would have huge impacts on the field of mammalogy.

In the 1960s, *The Mammals of North America* (Hall and Kelson 1959) quickly became a veritable landmark publication and the emphasis for new undertakings; it summarized everything then known about the distribution and taxonomy of native mammals in North America, and it included detailed range maps of every species. Much of the explosion of taxonomic research (especially on relationships within genera and geographic variation within species) was a direct result of studies leading to or stimulated by publication of



this epic monograph. Simpson (1964) used the range map database from Hall and Kelson's publication to quantify patterns of species diversity across the North American continent. Taxonomic catalogues published during the decade included those of Hershkovitz (1966) on living whales and Anderson and Jones (1967) on mammals of the world. From the 1970s to the end of the 20<sup>th</sup> century, there were fewer taxonomic catalogues published, but a large number of both "mammals of..." books and taxonomic revisions were issued. These types of publications would continue through the end of the century. Also, there was an upsurge of interest in physiological processes about mammals during the 1960s and 1970s, and the sub-discipline of landscape ecology and its application to mammalian ecology emerged.

Beginning in the 1960s, field mammalogists began to greatly diversify the types of information obtained and recorded from collected specimens. The expansion of data collection, particularly the advent of archiving and cataloging "frozen tissues," rendered the typical museum specimen into a true voucher specimen. One of the major advances in systematic biology occurred in 1950 when Willi Hennig published *Grundzüge einer Theorie der Phylogenetischen Systematik*, which was translated into English under the title *Phylogenetic Systematics* (Hennig 1966). Phylogenetic principals soon came to dominate the thinking of systematists and eventually were adapted as one of the primary sources for discussing evolutionary change.

The presence and role of women in mammalogy began to change dramatically in the 1960s. As noted earlier, several women played instrumental roles in the early days of the discipline; however, few women were trained in the major academic and professional centers for mammalogy before the late 1960s. By the end of the century, two women would serve as President of the ASM, and subsequently two more were elected to the office in the first two decades of the 21<sup>st</sup> century.

Methodological breakthroughs in the field of cytogenetics in the 1960s triggered a major thrust in this research area worldwide. Instrumental in the application of these new methods to the study of mammalian cytogenetics was T. C. Hsu at the University of Texas, M.D. Anderson Hospital and Tumor Institute (now

known as the M.D. Anderson Cancer Center). Dr. Hsu developed and applied chromosomal methods to the study of mammalian species. Further, he developed outlets such as the *Mammalian Chromosomes Newsletter* (published by M.D. Anderson Hospital and Tumor Institute, Section of Cytology, 1960 thru 1986) and *An Atlas of Mammalian Chromosomes* (authored by Hsu with Kurt Benirschke, in multiple volumes beginning in 1967) for reporting results of chromosomal variation in mammals. Later, chromosome researchers such as Robert J. Baker and James L. Patton, both graduate students at the University of Arizona, and Charles F. Nadler began to publish cytogenetics studies in the *Journal of Mammalogy*, bringing the journal into the mainstream of cytogenetics research.

Electrophoresis of blood and tissue proteins and enzymes came into wide use in the late 1960s (Lewontin and Hubby 1966; Hubby and Lewontin 1966), marking the onset of "molecular biology". Until the late 1980s, this technique was an effective tool in assessing the genetic architecture of populations and in measuring relatedness among groups.

In the 1970s and early 1980s, powerful computer software packages for organizing and analyzing data, using multivariate statistics, and clustering techniques became available, bringing statistical analysis to the forefront of many publications in mammalogy. Sub-disciplines that used computer modeling included population biology, energetics, and systematics.

As the 1970s transitioned into the 1980s, methods for differential-staining of chromosomes led to phylogenetic hypotheses for relations among mammals at nearly all taxonomic ranks. Building upon this technique, theoretical studies investigated the roles of chromosomal evolution, mutation rates, deme-size, canalization of karyotypes, and karyotypic evolution. Robert J. Baker, along with his students at Texas Tech University, was an early pioneer in the application of these techniques to mammalogy.

The 1980s began with publication in 1981 of E. Raymond Hall's long-awaited update of *The Mammals of North America*. Another useful catalogue published during the decade was the 1984 edition of Sydney Anderson and J Knox Jones' synopsis of mammals of

the world. Also, new techniques became available for studying mammals, such as night-vision scopes and radio-telemetry to watch and monitor, respectively, the movements and behavior of animals.

In addition to the aforementioned highlights, the timeline for this period (Table 4) reveals the emergence of new scientific societies and journals that reflected the growing specialization in mammalogy; the focus on sub-groups of mammals (bats, marine mammals, primates); and the growing interest in the conservation of mammals. Also, new and more extensive textbooks,

providing more comprehensive coverage of mammalian biology, appeared and underwent several revisions.

During the 1980s and early 1990s, technological advances in DNA methodologies allowed for previously complicated and expensive methods to be conducted at university research laboratories across North America. At first, these new DNA methods revolutionized systematic mammalogy, but later population genetics, ecology, behavioral, and other mammalian fields of study benefited from the vast amounts of information available in DNA based studies.

Table 4. Significant events in North American mammalogy during the Theoretical and Technological Phase, 1961–2000.

Year(s)	Event
1961	The World Wildlife Fund is established with a mission to raise money on behalf of vanishing species throughout the world.
1962	Rachel Carson publishes <i>Silent Spring</i> (Houghton Mifflin, Boston) describing the ecological dangers of pesticides.  E. Lendell Cockrum publishes <i>Introduction to Mammalogy</i> (Ronald Press, New York) a textbook for university mammalogy courses. This textbook emphasized taxonomy, keys, and distribution of mammals.
1963	Ernst Mayr publishes <i>Animal Species and Evolution</i> (The Belknap Press of Harvard University Press, Cambridge). This book provided the theoretical framework for the application of the biological species concept in systematic mammalogy.  Robert R. Sokal and Peter H. A. Sneath publish <i>Principles of Numerical Taxonomy</i> (W. H. Freeman and Co., San Francisco) describing the theory and methodology of phenetic approaches to taxonomy. This book is re-issued with Sneath as the senior author in 1973. Many systematic mammalogists adopt this methodology in studies of interspecific and intraspecific variation among mammals.  Membership of the ASM passes the 2,000 mark.  <i>Folia Primatologia: International Journal of Primatology</i> is established.  David E. Davis and Frank B. Golley publish the textbook <i>Principles in Mammalogy</i> (Reinhold Publishing, New York). Differing from Cockrum's textbook, this volume focuses more on ecological principles such as behavior, metabolism, energetics, and reproductive processes.  The IUCN Red List of Threatened Species (also known as the IUCN Red List or Red Data List) is published. This is the world's most comprehensive inventory of the global conservation status of biological species, including mammals.
1964	Ernest P. Walker et al. complete their two-volume work <i>Mammals of the World</i> (Johns Hopkins Press, Baltimore, Maryland), which provides a great reference work on mammals in which each genus and its characteristics and habits are summarized. This book was revised by John Paradiso in 1968 and in 1975. Since 1983, Ronald Nowak has revised this work (4 <sup>th</sup> edition, 1983; 5 <sup>th</sup> edition, 1991; 6 <sup>th</sup> edition, 1999).  George Gaylord Simpson in his paper "Species diversity of North American Recent mammals" (Systematic Zoology 13:57–73) uses Hall and Kelson's (1959) distribution maps as a database to quantify patterns of species diversity across the continent.

Table 4. (cont.)

Year(s)	Event
	<p>Lee Saunders Crandall publishes <i>The Management of Wild Animals in Captivity</i> (University of Chicago Press, Chicago). The publication was the culmination of 50 years of observation on the feeding, housing, reproduction, and longevity of the animals at the Bronx Zoo, with references from zoos around the world.</p> <p>The Wilderness Act is passed by Congress, creating the National Wilderness Preservation System. Wilderness designation is a protective overlay Congress applies to selected portions of national forests, parks, wildlife refuges, and other public lands. Today, the NWPS encompasses more than 100 million acres of federally owned land in 44 states and Puerto Rico. Many of these places are refuges for rare and threatened mammals.</p> <p>The International Biological Program (IBP) is founded to coordinate large-scale ecological and environmental studies. IBP was an attempt to apply the methods of big science to ecosystem ecology and pressing environmental issues. In 1968, the United States became heavily involved, including several North American mammalian ecologists. IBP sponsored five biome studies, including the Grassland Biome project.</p>
1966	<p>The English translation of Willi Hennig's book on cladistics and systematics, <i>Phylogenetic Systematics</i> (University of Illinois Press, Urbana), translated by D. Dwight Davis and Rainer Zangerl, is published. Phylogenetic principals soon came to dominate the thinking of systematists and eventually were adapted as one of the primary sources for discussing evolutionary change.</p> <p>Phillip Hershkovitz publishes "Catalog of living whales" (Bulletin of the United States National Museum 246:1–259), providing a checklist of the whales and dolphins of the world's waters.</p> <p>The Animal Welfare Act is passed, which regulates animal testing on vertebrates. The Act requires institutions to maintain Institutional Animal Care and Use Committees.</p> <p>Charles F. Nadler and Charles E. Hughes introduce the <i>Journal of Mammalogy</i> to chromosomes, and researchers like Jim Patton and Robert Baker and their students begin to dominate the mammalian chromosome literature.</p> <p>Richard C. Lewontin and John L. Hubby publish "A molecular approach to the study of genic heterozygosity in natural populations. II. Amount of variation and degree of heterozygosity in natural populations of <i>Drosophila pseudoobscura</i>" (Genetics 54:595–609), setting the stage for mammalian allozyme studies.</p>
1967	<p>The first <i>Special Publication</i> of the American Society of Mammalogists, "The natural history and behavior of the California sea lion", by Richard S. Peterson and George A. Bartholomew, is published. ASM has produced 13 <i>Special Publications</i>, the most recent being in 2005.</p> <p>Sydney Anderson and J Knox Jones, Jr., edit a compilation of chapters about <i>Recent Mammals of the World: Synopsis of Families</i> (Ronald Press Co., New York). An extensively revised and expanded version, retitled <i>Orders and Families of Recent Mammals of the World</i> (John Wiley and Sons, New York), is published in 1984. Each family is covered in detail with information including diagnosis, distribution, general habits, and general notes.</p> <p>Robert H. MacArthur and Edward O. Wilson publish "The Theory of Island Biogeography" (Monographs in Population Biology, Princeton University Press, Princeton 1:1–203), in which the authors attempt to predict species richness based on island size (area) and isolation (distance). Mammalogists apply the theory to mountain biogeography and conservation studies.</p> <p>T. C. Hsu with Kurt Benirschke publish the first volume of <i>An Atlas of Mammalian Chromosomes</i>. This compilation of images of mammalian karyotypes is published in 10 volumes through 1977.</p>



Table 4. (cont.)

Year(s)	Event
1968	<p>Membership in the ASM passes 3,000.</p> <p>James Brown and Carl Welser publish the first <i>Journal of Mammalogy</i> article on allozymes and population genetics, which quickly mushrooms into a field of its own with the works of Robert K. Sealander, John Avise, and Michael Smith at the Savannah River Ecology Laboratory.</p> <p>SPSS Statistics, a software package (for use on mainframe computers, at the time) used for logical batched and non-batched statistical analysis, is released. Acquired by IBM in 2009, the current versions (most recent, 2015) are officially named IBM SPSS Statistics. This package allowed mammalogists to perform multivariate statistics on large datasets using university computers.</p> <p>The term “biological diversity” is first used by wildlife ecologist and conservationist Raymond F. Dasmann in <i>A Different Kind of Country</i> (Macmillan Publishers, New York). The term was not widely adopted until more than a decade later, when it came into common usage in science and environmental policy in the 1980s. The contracted form “biodiversity” was coined by W.G. Rosen while planning the 1986 National Forum on BioDiversity, organized by the National Research Council/National Academy of Sciences and Smithsonian Institution. It first appeared in a publication in 1988 when Edward O. Wilson used it as the title of the proceedings of that forum.</p>
1969	<p>The ASM Board of Directors vote to establish <i>Mammalian Species</i>, the brainchild of Sydney Anderson, as an official publication of the Society. The objective of the publication “is to provide a critically compiled, accurate, and concise summary of the present state of our biological knowledge (and ignorance) of a species of mammal in a standard format.”</p> <p>Joseph G. Gall and Mary L. Pardue publish “Formation and detection of RNA-DNA hybrid molecules in cytological preparations” (Proceedings of the National Academy of Sciences of the United States of America 63:378–383), setting the stage for in situ hybridization and other gene localization methods. This paved the way for later studies involving gene mapping.</p> <p>Allan Wilson and Vince Sarich (“A molecular time scale for human evolution,” Proceedings of the National Academy of Sciences 63:1088–1093) argue that the origins of the human species can be seen through a ‘molecular clock’. This becomes a way of dating not from fossils but from genetic mutations that have accumulated since they departed from a common ancestor. The concept has been applied to numerous other mammalian species.</p> <p>Charles Krebs and colleagues (Ecology 50:587–607) describe population cycles in small rodents and how dispersal is important to the persistence of populations.</p> <p>Volume 50, Issue 4 of the <i>Journal of Mammalogy</i> includes two articles honoring the 50th anniversary of the American Society of Mammalogists (Donald F. Hoffmeister, “The first fifty years of the American Society of Mammalogists,” pp. 794–802; Tracy I. Storer, “Mammalogy and the American Society of Mammalogists, 1919–1969,” pp. 785–793).</p>
1970	<p>First Southwestern Symposium on Bat Research is held in Tucson, Arizona. In 1972, the name of the meeting was changed to the North American Symposium on Bat Research, and they continue to meet annually. The North American Society for Bat Research is dedicated to the promotion and development of the scientific study of bats.</p>
1970–1971	<p>Mary L. Pardue and Joseph G. Gall (Science, 1970, 168:1356–1358), Frances E. Arrighi and T. C. Hsu (Cytogenetics, 1971, 10:81–86), Marina Seabright (Lancet, 1971, 2:971–972), and Adrian T. Sumner et al. (Nature, 1971, 232:31–32) publish articles on cytogenetics and differentially-stained chromosomes, setting the stage for chromosome banding studies in mammals.</p>

Table 4. (cont.)

Year(s)	Event
1971	<p>The ASM establishes the Grants-in-Aid Committee to enhance and support graduate research by identifying and funding research proposals pertaining to mammals. In the 21<sup>st</sup> century, this program has come to receive at least 100 proposals per year and to fund 35–50% of them. This is perhaps the largest outlet for graduate research funds to study mammals and has become a major vehicle for training many recent prominent mammalogists.</p> <p>James Brown publishes “Mammals on mountain tops: Non-equilibrium insular biogeography” (<i>American Naturalist</i> 105:467–478), applying the MacArthur and Wilson theory of island biogeography to insular mammal faunas.</p>
1972	<p>Congress passes the Marine Mammal Protection Act (MMPA), which makes it illegal to hunt or otherwise do damage to marine mammals. Enforcement is under the jurisdiction of the U.S. National Marine Fisheries Service for whales, dolphins, porpoises, and pinnipeds, and the U.S. Fish and Wildlife Service for walrus, polar bears, sea otters, and manatees.</p> <p>Terry Vaughan publishes <i>Mammalogy</i> (W. B. Saunders Co., Philadelphia), which becomes a popular textbook for teaching mammalogy. It is revised and published again in 1978 and 1986. In 2000, Vaughan, James M. Ryan, and Nicholas J. Czaplewski publish the 4<sup>th</sup> edition (Saunders College Publishing, Ft. Worth, Texas). Six editions of the text have now been published, with the latest in 2013 by Jones &amp; Bartlett Learning.</p> <p>The <i>Wildlife Society Bulletin</i> is established as an outlet for wildlife-related articles, including those about game and non-game mammals.</p> <p>Robert MacArthur publishes <i>Geographical Ecology: Patterns in the Distribution of Species</i> (Harper &amp; Roe, New York), in which he summarizes and explains the mathematical treatment behind species abundance and diversity, competition and resource utilization, life history theory, optimal foraging, and island biogeography. MacArthur’s papers and book would earn him recognition as the most influential ecologist of his generation.</p>
1973	<p>The Endangered Species Act (ESA) is passed by Congress to protect endangered plants and animals. Building upon legislation passed in 1966 and 1969, the new law expands and strengthens efforts to protect species domestically and internationally. The Fish and Wildlife Service and the National Marine Fisheries Service assume responsibility for administering the ESA.</p> <p>J Knox Jones, Jr., and other authors publish a “Checklist of North American mammals north of Mexico” (<i>Occasional Papers, Museum of Texas Tech University</i> 12:1–4). This checklist is periodically updated, with various authors, to reflect new taxonomic and distributional information (1975, 1979, 1986, 1992, 1997, 2003, and 2014).</p> <p>James S. Findley applies phenetics to characterize the morphological and trophic structure of bat communities (<i>American Naturalist</i> 107:580–584). This publication began the broad use of ecomorphological approaches to understand the ecology of mammals.</p> <p>Don Wilson publishes “Bat faunas: a trophic comparison” (<i>Systematic Zoology</i> 22:14–29), examining the distribution in different dietary groups of taxa in faunas around the world. This publication was instrumental in demonstrating the substantial trophic diversity of New World faunas that result primarily from Phyllostomidae.</p> <p>Catherine Ralls publishes “Mammals in which females are larger than males” (<i>Quarterly Review of Biology</i> 51:245–276), describing widespread female biased sexual dimorphism in mammals and presenting the “Big Mother” hypothesis.</p>
1974	<p>Anthony F. DeBlase and Robert E. Martin publish <i>A Manual of Mammalogy with Keys to the Families of the World</i> (William C. Brown Publishing, Dubuque, Iowa). A second edition is published in 1981, and a third edition is published by McGraw-Hill Inc. in 2000, with Ronald H. Pine as a co-author.</p>

Table 4. (cont.)

Year(s)	Event
	<p>International Theriological Congress is established and the first meeting is held in Moscow, Russia. In 2005, it was renamed the International Mammalogical Congress. Meetings are held every three years.</p> <p>The ASM establishes the C. Hart Merriam Award to recognize exceptional contributions to the discipline of mammalogy within the last decade. The first recipient is James N. Layne in 1976.</p> <p>Alexander W. F. Banfield publishes <i>The Mammals of Canada</i> (University of Toronto Press, Toronto, Canada). This is the first and only comprehensive handbook to the mammals of Canada, providing accounts of 196 species.</p>
1975	<p>The Convention on International Trade in Endangered Species (CITES) comes into force after having been agreed to in 1963. Its aim is to ensure that international trade in specimens of wild animals, including mammals, and plants does not threaten the survival of the species in the wild. CITES works by subjecting international trade in specimens to certain controls. All import, export, re-export, and introduction from the species covered by the Convention has to be authorized through a licensing system.</p> <p>Edward O. Wilson publishes <i>Sociobiology, the New Synthesis</i> (Harvard University Press, Cambridge). This volume formalized and initiated the great debate on nature versus nurture and their roles in the behavioral decisions of animals, in particular those of nurturing of offspring, altruism, and communication.</p>
1976	<p>Harvey Gunderson publishes a textbook <i>Mammalogy</i> (McGraw-Hill, New York).</p> <p>J Knox Jones, Jr., publishes "Selected readings in mammalogy: Selected from the original literature and introduced with comments by J Knox Jones, Jr., Sydney Anderson, and Robert S. Hoffmann" (Museum of Natural History, University of Kansas, Monograph 5:1–640) for use in teaching an advanced graduate course in the discipline. The volume includes a series of classic papers written about mammals to that date.</p> <p>Timothy E. Lawlor publishes a <i>Handbook to the Orders and Families of Living Mammals</i>, 2<sup>nd</sup> edition (Mad River Press, Eureka, California). It provides keys and diagnostic descriptions of the orders and families of mammals around the world. A second, more widely used edition, is published in 1979.</p> <p>ASM establishes the Legislation and Regulations Committee in response to the need for monitoring and providing input into the rapidly burgeoning state and federal legislation and regulations in such areas as endangered species, steel-trapping regulations, and use of animals for experimental purposes of direct concern to mammalogy.</p> <p>The software suite SAS, developed by SAS Institute for advanced analytics, multivariate analyses, business intelligence, data management, and predictive analytics, is released. SAS was further developed in the 1980s and 1990s with the addition of new statistical procedures and components. A point-and-click interface was added in 2004, and a social media analytics product was added in 2010. This software package allowed analyses to be run by lay statisticians.</p> <p>Robert J. Baker and colleagues begin collecting mammal tissue samples and preserving them in liquid nitrogen in the field for the purposes of archiving them at the Natural Science Research Laboratory of the Museum of Texas Tech University. Other researchers soon follow suit with this practice and "tissue collections" become affiliated with many collections of mammals.</p>
1977	<p>The Mammal Slide Library Committee of ASM is established to provide low-cost slides of mammals, often in natural habitats, principally for educational purposes.</p> <p>The Hartley H.T. Jackson Award is established by the ASM to recognize members who have given long and outstanding service to the society. William B. Davis is the first recipient of the award in 1978.</p>



Table 4. (cont.)

Year(s)	Event
1978	Robert J. Baker and Hugh H. Genoways describe the island biogeography of bats in the Caribbean Basin (Academy of Natural Sciences of Philadelphia 13:53–97). This is the first comprehensive account of the distribution of bats across a large oceanic archipelago; this formed the basis for numerous comparative analyses in island biogeography that continue today.
1979	James Brown, Diane Davison, and James Reichman publish results of exclosure experiments on seed eating rodent communities near Tucson, Arizona (American Zoologist 19:1129–1143). This is the first large-scale manipulative experiment imposed on mammal communities. Among other things, these experiments illuminated the importance of competition, both among rodents but also among rodents and ants, on the structure of mammalian communities.  Membership in ASM exceeds 3,900.
1980	The Checklist Committee is established by the ASM to maintain and provide advice on forthcoming publications of the mammal species of the world.  Michael E. Soule and Bruce A. Wilcox publish <i>Conservation Biology, An Evolutionary-Ecological Perspective</i> (Sinauer Associates, Sunderland, Massachusetts). The term ‘conservation biology’ is defined and becomes a prominent focus of research on mammals to the present day.  The <i>International Journal of Primatology</i> is established.  Gordon B. Corbet and John E. Hill publish <i>A World List of Mammalian Species</i> (British Museum of Natural History, London). Each entry includes scientific name, English common name, and geographical range with selected line drawings. The volume is revised and re-issued in 1986 (2 <sup>nd</sup> edition) and 1991 (3 <sup>rd</sup> edition).  The IUCN, in cooperation with the United Nations Environment Program (UNEP) and the World Wildlife Fund (WWF), issue the World Conservation Strategy, which seeks to thwart exploitation of the earth’s seas and soils by shifting to the concept of ‘sustainable development’, a phrase that becomes an important part of the conservation vocabulary used for plant and animal populations, including mammals.  The U.S. LTER (Long Term Ecological Research) network was established by NSF as a network of independent reserves where long-term research that spans decades and large geographic areas is conducted.
1981	A revised edition of <i>The Mammals of North America</i> (John Wiley & Sons, New York, 2 volumes) is published with E. Raymond Hall as the sole author.  The Society for Marine Mammalogy is founded in San Francisco, California.  John Eisenberg publishes <i>The Mammalian Radiations: An Analysis of Trends in Evolution, Adaptation and Behavior</i> (University of Chicago Press, Chicago). The book presents a selected synthesis of mammalian biology in an adaptive, behavioral, and evolutionary perspective for all of the continents.  Edward O. Wiley publishes <i>Phylogenetics: The Theory and Practice of Phylogenetic Systematics</i> (John Wiley and Sons, New York). This book provided a theoretical framework for much of the early work in cladistical approaches used to study mammalian systematics.
1981–1998	Sam H. Ridgway and Richard Harrison edit <i>Handbook of Marine Mammals</i> , six volumes (Academic Press Inc., New York). This treatise covers the biology and life history of marine mammals as well as their distribution and identification. Each volume covers a group of related animals.
1982	J. Mary Taylor is the first woman to be elected president of the American Society of Mammalogists. Prior to that time, Viola S. Schantz and Caroline A. Heppenstall were the only women to hold office, that of treasurer. To date, only three other women have served as president of ASM—Alicia Linzey (1996–1998), Suzanne McLaren (2008–2010), and Eileen Lacey (2014–2016).

Table 4. (cont.)

Year(s)	Event
	James H. Honacki et al. publish the first <i>Mammal Species of the World</i> (Allen Press and the Association for Systematics Collections, Lawrence, Kansas).
	Eduardo H. Rapoport publishes <i>Areography, Geographical Strategies of Species</i> (Pergamon Press, Oxford) as a new methodological approach for assessing distributional patterns of North American mammals.
	GenBank is established as an open access, annotated collection of gene sequences from organisms, including mammals, produced in laboratories throughout the world. Since then, other websites have been developed for public access and management of protein and genome datasets.
1983	The American Society of Mammalogists publishes “Advances in the study of mammalian behavior” (Special Publication 7:1–753), by John F. Eisenberg and Devra G. Kleiman, marking the recognition that studies of mammalian behavior had come of age.
	James H. Brown and Arthur C. Gibson publish <i>Biogeography</i> (C. V. Mosby, St. Louis), which examines the evolutionary, ecological, and geological processes that have influenced the distribution of plants and animals across the world. The book includes many examples about mammals.
	David L. Swofford releases PAUP (Phylogenetic Analysis Using Parsimony), a computational phylogenetics program for inferring evolutionary trees (phylogenies). With the release of version 4.0 in 1996, the program became known as PAUP* (Phylogenetic Analysis Using Parsimony and other methods) and supported distance matrix and likelihood methods. The software allowed mammalogists to quickly conduct phylogenetic analyses.
	Joel Cracraft publishes “Species concepts and speciation analysis” (Pp. 159–187 in <i>Current Ornithology</i> , Volume 1, Plenum Press, New York), establishing the phylogenetic species concept, which defines a species, in its simplest form, as the smallest diagnosable cluster of individual organisms within which there is a paternal pattern of ancestry and descent.
1984	The Asociación Mexicana de Mastozoología, A. C.—the AMMAC or Mexican Mammal Society—is established in Mexico. The society has flourished with several hundred members, and now holds an annual meeting and publishes a journal, <i>Therya</i> .
1985	The Health Research Extension Act provides the legislative mandate for the Public Health Service Policy of Human Care and Use of Laboratory Animals.
	The Society for Conservation Biology is founded to enhance the scientific study of the maintenance, loss, and restoration of biological diversity.
	The journal <i>Marine Mammal Science</i> , published by the Society for Marine Mammalogy, is established to publish articles on all aspects of marine mammal biology.
1986	Camera traps are used to survey nocturnal felids (J. H. Rappole, D. Navarro-Lopez, M. Tewes, and D. Everett, Remote-trip cameras as a means for surveying for nocturnal felids, Pp. 45–52 in <i>Nocturnal mammals: techniques for study</i> , R. P. Brooks, ed., School of Forest Research Papers, Pennsylvania State University 48:1–57). Although first reported in 1919, this methodology, with the advent of infrared sensors and digital cameras, is now widely used to census and study a variety of mammal species.
1987	The Animal Care and Use Committee is established as a study committee of the ASM to serve as a liaison to society members on matters relating to the care and use of wild mammals.
	<i>Peterson First Guide to Mammals of North America</i> (Houghton Mifflin Harcourt, Boston, Massachusetts) is published. This paperback, low-cost guide is intended for the amateur naturalist interested in mammals and is revised and re-issued periodically.

Table 4. (cont.)

Year(s)	Event
	Ulla Norberg and Jeremy Rayner publish a monograph on “Ecological morphology and flight in bats” (Philosophical Transactions of the Royal Society 316:337–419). This was the first and perhaps most comprehensive study of the ecomorphology of bat wings and its implications for flight performance, foraging strategies, and echolocation.
1988	Theodore Fleming publishes <i>The Short-tailed Fruit Bat</i> (University of Chicago Press, Chicago), the most comprehensive monograph in the ecology of any bat species to date.
1989	Gap Analysis is developed by the U.S. Fish and Wildlife Service as a scientific method for identifying the degree to which native animal species and natural plant communities are represented in present day networks of conservation lands. The methodology is adapted and used by mammalian conservationists. ASM establishes the Latin American Field Research Award to support field research projects by Latin Americans in Latin America.
1990	Michael J. Novacek publishes “Morphology, paleontology, and the higher clades of mammals” (Current Mammalogy 2:507–543), which proposes a new classification of mammalian orders using cladistic methodology. The Human Genome Project is initiated with the objective of determining the DNA sequence of the entire euchromatic human genome within 15 years.
1992	The ASM Animal Care and Use Committee becomes a standing committee, reflecting the growing importance and impact guidelines have on research with both wild and laboratory mammals. J Knox Jones, Jr. and Richard W. Manning publish <i>Illustrated Key to Skulls of Genera of North American Land Mammals</i> (Texas Tech University Press, Lubbock). Brock Fenton et al. (Biotropica 24:440–446) demonstrate that phyllostomine bats are sensitive indicators of habitat disruption thereby bringing disturbance to the forefront of mammalian community ecology.
1993	The National Biological Survey (“Survey” later changed to “Service”) is established by Bruce Babbitt, Secretary of the Interior in the Clinton Administration, as a new research agency within the Department of Interior (DOI). The new agency was staffed with 1,200 scientists and 600 other employees transferred from seven DOI agencies. Ron Pulliam, an avian ecologist, is appointed Director, and James Reichman, a small-mammal ecologist, served as Assistant Director. Following a Republican take-over of Congress in 1995, the agency was transferred into DOI’s U.S. Geological Survey to become that agency’s new Biological Resources Division. GIS Applications in Mammalogy (S. H. McLaren and J. K. Braun, eds., Oklahoma Museum of Natural History, Norman) is published describing the various applications of GIS mapping tools in spatial studies of mammalian ecology. GIS is a collection of computer programs known as Geographical Information Systems. The <i>Journal of Mammalian Evolution</i> is established and devoted to studies of the comparative morphology, molecular biology, paleobiology, genetics, developmental and reproductive biology, biogeography, systematics, ethology and ecology, and population dynamics of mammals and the ways that these diverse data can be analyzed for the reconstruction of mammalian evolution. Frederick Szalay, Michael J. Novacek, and Malcolm C. McKenna edit a two-volume work on <i>Mammal Phylogeny</i> (Springer-Verlag, New York). Volume 1 covers the phylogeny of extinct groups, monotremes, and marsupials; Volume 2 covers placentals.



Table 4. (cont.)

Year(s)	Event
	Don E. Wilson and DeeAnn M. Reeder publish the second edition of <i>Mammal Species of the World</i> (Johns Hopkins University Press, Baltimore), a significant improvement over the Honacki et al. 1982 version. A third edition of this work, with further improvements, is published in 2005. This edition includes common names, authorities for synonyms, and the recognition of subspecies. It also includes a compendium of higher level mammalian taxa.
1994	The ASM publishes <i>Special Publication</i> Volume 11, "Seventy-five years of mammalogy (1919–1994)," edited by Elmer C. Birney and Jerry R. Choate, containing 21 articles about the history of the ASM and the intellectual development of the discipline of mammalogy.
1995	James H. Brown publishes <i>Macroecology</i> (University of Chicago Press, Chicago). The book argues for the integration of data from ecology, systematics, evolutionary biology, paleobiology, and biogeography to better predict how patterns of life have formed across the earth over time. The main focus of the new subdiscipline of macroecology is to explain why highly nonrandom patterns in distribution and abundance, as well as statistical distributions of body size, range size, and abundance of large clades of organisms such as class Mammalia, are so similar across taxa. Brown, a noted mammalogist, provides numerous examples using mammals.
	William Lidicker publishes the edited volume <i>Landscape Approaches in Mammalian Ecology and Conservation</i> (University of Minnesota Press, Minneapolis), the first synthetic treatment of mammalian landscape ecology.
	Wolves are reintroduced to the Lamar Valley of Yellowstone National Park. This milestone rekindles the debate between biologists and the public over the ecosystem value of predators versus predator control.
1996	The first cloned mammal, "Dolly the sheep," is born at Roslin Institute, University of Edinburgh.
	The ASM establishes the Joseph Grinnell Award to honor individuals who have made outstanding and sustained contributions to education in mammalogy over a period of at least 10 years. The first recipient is B. Elizabeth Horner in 1997.
	The National Biological Service is transferred to the newly created Biological Resources Division of the U.S. Geological Survey.
	John O. Whitaker and National Audubon Society staff produce the <i>National Audubon Society Field Guide to North American Mammals</i> (Knopf Publishing, New York). First published by a different author in 1980, this field guide contains more than 300 accounts of species along with photographs.
	David Scheel, T. L. S. Vincent, and Guy Cameron ( <i>Conservation Biology</i> 10:452–464) are the first to estimate changes in geographic distribution of bats due to climate change and how that would affect patterns of species richness.
	Volume 77, Issue 3 of the <i>Journal of Mammalogy</i> includes a Special Feature (pp. 609–674) containing five articles dedicated to the history, contributions, and changing role of women in North American mammalogy and the American Society of Mammalogists.
1997	Mark S. Hafner et al. publish <i>Mammal Collections in the Western Hemisphere: A Survey and Directory of Existing Collections</i> (American Society of Mammalogists, Lawrence, Kansas). It presents the results of an extensive 1995 survey of mammal collections and contains information on the size, contents, taxa represented, presence of catalogues or various policies, and similar data.
	Malcolm C. McKenna and Susan K. Bell publish <i>Classification of Mammals above the Species Level</i> (Columbia University Press, New York). This is a comprehensive work on systematics, relationships, and occurrences of all mammal taxa, living and extinct, down through the rank of genus. It was revised in 2000.

Table 4. (cont.)

Year(s)	Event
1998	Dale W. Rice's, "Marine mammals of the world: Systematics and distribution" (Society for Marine Mammalogy, Special Publication 4:1–230) updates his previously published "A list of the names of Recent species of marine mammals." Each entry includes scientific and English common names, a review of published studies on geographic variation, and geographical distribution.
1999	Don E. Wilson and Sue Ruff (editors) publish <i>The Smithsonian Book of North American Mammals</i> (Smithsonian Institution Press, Washington, D.C.). This is a compilation of species accounts by more than 200 experts for all known species north of Mexico.  The American Society of Mammalogists issues another statement condemning indiscriminate predator control by Wildlife Services.  George A. Feldhamer publishes <i>Mammalogy</i> (McGraw-Hill, Dubuque, Iowa). Additional co-authors are added and subsequent editions (2003, 2007, 2015) are published by Johns Hopkins Press.
2000	Don Wilson and F. Russell Cole publish <i>Common Names of Mammals of the World</i> (Smithsonian Institution Press, Washington, D.C.). It contains a list of the standard common names for 4,629 species of mammals, introducing many new names. The list is arranged in phylogenetic order and includes order and family names as well as those of genera and species.  John Avise publishes <i>Phylogeography</i> (Harvard University Press, Boston), a discipline concerned with various relationships between gene genealogies, phylogenetics, and geography. Many mammalogists adopt the theory and procedures to study various groups of mammals.  A. Townsend Peterson et al. (Biological Conservation 93:85–94) author "Geographic analysis of conservation priority: Endemic birds and mammals in Veracruz, Mexico". This paper represents the first application of the ecological niche model to mammals.

## 21<sup>ST</sup> CENTURY: THE BIG DATA PHASE: MOLECULAR BIOLOGY AND QUANTITATIVE ECOLOGY

The new millennium brought with it information that had amassed over more than 150 years of mammalogy in North America. As we progress into the 21<sup>st</sup> century, much life history, natural history, and other ecological data have amassed to allow investigation of more synthetic questions regarding mammalian ecology and evolution. The molecular age of evolutionary biology and systematics offered a wealth of data on different genetic markers and numerous powerful quantitative approaches to better estimate phylogenies of diverse groups of mammals. Similarly, in ecology and biogeography, large compendia on mammalian distributions, such as *Mammals of North America* (Hall 1981), Nature Serve's *Digital Distribution Maps of Mammals of the Western Hemisphere* (Patterson et al. 2007), and distribution maps provided by the IUCN (2017), provided comprehensive data from which to examine spatial distribution of mammals from local to global scales. "Data Papers" published by the Ecological Society of America made available large sets of raw

data for use in ecological analyses. Notable examples are Thibault et al. (2011) for terrestrial mammal communities distributed across the world and Muylaert et al. (in press) for bat communities distributed across South America.

As is true in many fields of biology, molecular genetics now dominate most aspects of mammalogical research. Molecular-based research methods are being used in nearly every subdiscipline of the discipline. The extraordinary advances of the late 20<sup>th</sup> and early 21<sup>st</sup> centuries have allowed mammalogists to use DNA-based methods to examine much more than phylogenetic questions. For example, the modern mammalogist can now determine parentage, relatedness among individuals, levels of hybridization and direction of introgression, phylogenetic relationships across all taxonomic ranks, selection on individual genes, metagenomic and genomic variability, and the list goes on. Using these approaches, investigators can

now evaluate a myriad of other parameters, such as breeding success of individuals, fitness of populations, individual mating strategies, physiological, dietary, and other ecological and evolutionary adaptations, and differential gene expression.

Molecular biology is a research field that the founders of the American Society of Mammalogists probably never imagined. The power of the various approaches is reaching a point where the impossible is becoming the norm. For example, twenty years ago a mammalogist could set a few hair traps (pieces of wire for snagging hair) in an area in hopes of collecting hair samples of a carnivore (for example, a black bear). Perhaps the mammalogist also collected a few scat samples that he/she was pretty certain were black bear in origin. The conclusions of this study likely would be limited to: 1) bears are present in the study area; 2) maybe more than one bear is present (some hairs appeared to be slightly different in color); and 3) based on scat analyses, bears appear to consume two species of berries and perhaps scavenge moose. In today's world, armed with the latest genomic and metagenomic tools (and some really good computational skills), that same dataset could be expanded to determine: 1) exactly how many bears were in the area, as well as their sex and whether they are related to each other; 2) if the bears were reproductively active; 3) exactly what the bears ate (perhaps to species level in all cases); 4) if the bears were resident bears, and more. Obviously, through molecular methods, we can extract many data points that were not available a few years ago.

During the last 20 years, we have seen molecular systematics expand from constructing single-gene phylogenies to studies that examine entire genomes. As of 2017, 43 mammalian genomes had been sequenced, and given the rapid change in methodology, it will not take long to sequence the next 43 genomes. With the availability of each mammalian genome or associated metagenome, mammalogy takes an exponential leap forward relative to the information that becomes available, as well as the potential for that information to generate additional data about important biological principles. Efforts appear to be underway to clone a mammoth during the next two years. It will be interesting to see how long the molecular phase lasts and what technological advances it brings to future mammalogists.

To keep up with the enormous volume of genetic data generated by improvements in molecular systematics, several advances have taken place on the data analysis front. Many of these are the result of technological developments in computing hardware and software but others are the result of innovations in quantitative and modelling methods that grew from new ideas in the conceptual and theoretical realms of data analysis. One such method involved methods for testing for significance among alternative trees (see Shimodaira and Hasegawa 1999), so that confidence could be assigned to a particular phylogeny relative to other topologies. Further methods (e.g. Bayesian Posterior probabilities – Huelsenbeck and Ronquist 2001) were developed to test for nodal support allowing the investigator to assign confidence (or not) to clades of interest. The ability to statistically reject (or accept) the topology of a clade greatly advanced the field of molecular systematics by inferring that phylogenies could be viewed as testable hypotheses.

Another example is seen with the development of the “supertree” concept. As researchers generated phylogenetic trees based on DNA sequences from different molecular markers, a need arose for a mechanism that would combine these multiple, individual trees into a larger, single tree (hence the term “supertree”) that could act as a summary tree. As a result of such efforts, robust phylogenies have been developed for many groups of mammals, and Bininda-Emonds et al. (2007) produced one of the most extensive datasets for examining the ordinal relationships of mammals. Further, researchers have used the supertree concept to compare phylogenies constructed from different datasets (i.e., different molecular markers, morphological characteristics, ecological patterns, etc.); this methodology greatly facilitates the examination of patterns of diversification across the entire class Mammalia.

A third innovation involved the ability to incorporate meaningful dates (divergence times) into phylogenetic analyses. Recently developed methods permit an investigator to calibrate divergence times within a phylogeny using information from fossil dates obtained from members of outgroup or ingroup taxa. This methodology allows the dates to be assigned for internal as well as terminal nodes within the phylogeny (see Bouckaert et al. 2014; Drummond and Rambaut 2007; Drummond et al. 2012), allowing for an interpretation



of patterns of diversification within the context of the geologic record. Further, because such phylogenetic trees are dated and effectively standardized via the fos-

sil record, trees obtained from different genetic markers become more comparable among studies.

Table 5. Significant events in North American mammalogy during the Big Data: Molecular Biology and Quantitative Ecology Phase, 2001–present.

Year(s)	Event
2001	<p>The Human Genome Project announces completion of the Public Genome Project, the initial draft and analysis of the human genome. The next day, Craig Venter and Celera Genomics publish their privately funded human genome sequence.</p> <p>William J. Murphy et al. publish “Molecular phylogenetics and the origins of placental mammals” (Nature 409:614–618), which revolutionizes earlier ideas about the evolution of mammals.</p>
2002	<p>Roland W. Kays and Don E. Wilson publish <i>Mammals of North America</i> (Princeton University Press, New Jersey). This guide contains accounts and photos of 442 species north of Mexico. Fully revised editions were published in 2009 and 2011.</p> <p>William P. Perrin, Bernd Würsig, and J. G. M. Thewissen (editors) publish the <i>Encyclopedia of Marine Mammals</i> (Academic Press, Cambridge). It contains 285 articles on all aspects of marine mammals, from anatomy to human interactions.</p> <p>David Attenborough publishes <i>The Life of Mammals</i> (British Broadcasting Company, United Kingdom) in conjunction with a television series of the same name. This colorful volume provides information on the natural history and evolution of mammals.</p> <p>The <i>Mus</i> genome is published by Waterston et al. (Nature 420:520–562).</p> <p>NSF initiates the program “Assembling the Tree of Life.” This is an ambitious program to fund large multi-institutional teams of investigators to resolve large groups of organisms, with the aim to ultimately combine all results to form a resolved Tree of Life.</p>
2003	<p>ASM establishes Oliver P. Pearson Award to support a young professional who holds an academic position in a Latin American institution within five years of receiving a Ph.D. or equivalent degree.</p> <p>ENCODE project is launched by the National Human Genome Research Institute and aims to identify and characterize all the genes in the human genome. This has led to successful annotations of genes in multiple mammalian genomes.</p>
2005	<p>Tom S. Kemp publishes <i>The Origin and Evolution of Mammals</i> (Oxford University Press, Oxford), which re-examines the evolution of mammals using recent fossil and DNA sequence evidence.</p> <p>James H. Brown, noted mammalogist and ecologist and the 37<sup>th</sup> president of the ASM (1990–1992), is elected to the National Academy of Sciences.</p> <p>Carleton J. Phillips and Clyde Jones compile and edit <i>Going Afield</i> (Museum of Texas Tech University, Lubbock) chronicling the lives and careers of 16 well-known mammalogists along with their perspectives on the development of mammalogy.</p>
2006	<p>Robert J. Baker and Robert D. Bradley propose the genetic species concept for mammals in a paper “Speciation in mammals and the genetic species concept” (Journal of Mammalogy 87:643–662). This paper revisits the genetic species concept that was proposed in the early 1900s and provides a set of criteria for applying this concept to mammals.</p> <p>Fiona A. Reid authors <i>Peterson Field Guide to Mammals of North American</i> (Houghton Mifflin Harcourt Co., Boston). This guide covers all of the mammals north of Mexico including near-shore waters.</p>

Table 5. (cont.)

Year(s)	Event
2009	The first volume of <i>Handbook of Mammals of the World</i> , edited by Don E. Wilson and Russell A. Mittermeier, is published (Lynx Edicions, Barcelona, Spain). Volumes 1–6 have now been published, Volume 7 is currently in press, and two additional and final volumes are planned.
2011	The results of the Broad Institute's 29 Mammals Project, which was initiated in 2006 and funded by NIH to expand the genome coverage (then human, mouse, dog, chimpanzee, and opossum) by sequencing 24 additional mammals, are published in "A high-resolution map of human evolutionary constraint using 29 mammals" (Nature 478:476–482).  National Science Foundation approves funding for the NEON (National Ecological Observatory Program) Program, a set of 81 field sites across the United States designed to collect standardized, high quality ecological data so that comparisons across the entire U.S. can be made.
2013–2014	Robert D. Bradley, Robert J. Baker, and colleagues publish a series of papers on the monetary value of museum specimens (Bradley et al., Occasional Papers of the Museum, Texas Tech University 313; Baker et al., Occasional Papers of the Museum, Texas Tech University 323; Bradley et al., BioScience 64:1150–1158). These papers help illustrate the cost and ultimately the value of maintaining natural history collections.
2014	Gerardo Ceballos edits and publishes <i>Mammals of Mexico</i> (Johns Hopkins University Press, Baltimore, Maryland) as the first comprehensive English reference on the more than 500 species of mammals in Mexico.  The complete genome of the Neanderthal is published by Kay Prufer et al. (Nature 505:43–49).
2017	Gerardo Ceballos, Anne H. Ehrlich, and Paul Ehrlich publish <i>The Annihilation of Nature</i> (Johns Hopkins University Press, Baltimore, Maryland). In this book, the authors argue that more than 80% of mammal species have declined significantly since 1990.

## DISCUSSION

The mammalogy timeline included herein is the most complete and detailed for any of the "ologies" in North America. cursory timeline histories have been produced by *Webster's Timeline History* series (compiled by Philip M. Parker of INSEAD) for mammalogy (2009) and herpetology (2009) but not for ornithology or ichthyology. Unfortunately, because these timelines were not developed by professionals associated with a particular discipline, they are lacking in crucial details, standard criteria, and presentation. For example, *Wikipedia* has a timeline for ornithology that is more detailed than the two Webster timelines, giving the impression of some professional input.

Our goal was to develop a detailed and complete timeline of scientific publications, methodologies, legislation, and other events that helped advance mammalogy in North America. As mentioned in the

Introduction, our timeline is biased toward what we as authors deemed important or relevant. Therefore, the timeline should not be viewed as the final word; instead, it should be treated as a framework to add other scientific works (excluded or forgotten by the current authors), events, methodologies, etc., as deemed important by the reader. Our hope is that professionals in the discipline will find the timeline useful as a quick reference and teaching guide to chronologies and important events. Further, we hope that students of mammalogy can use the timeline as a historical synopsis of the pertinent and relevant mammalogical/biological literature. Perhaps this timeline can serve the graduate student new to mammalogy and biology as well as the advanced student who is preparing for their qualifying exams.

## ACKNOWLEDGMENTS

We thank L. L. Lindsey, T. J. Soniat, J. Q. Francis, E. K. Roberts, and E. A. Wright for comments on various versions of this manuscript. Don E. Wilson and Alfred L. Gardner were kind enough to review the

manuscript and correct many errors of omission and text. However, the authors accept full responsibility for the final content.

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